DH CONSULTANCY BVBA

ODI Integration in SEPEM—Technical Note 2

SEPEM Data and System Updates

28 November 2018
V 1.2

This is Technical Note 2 for the ODI Integration in SEPEM, ESA Contract No 4000115930/15/NL/HK.

DOCUMENT INFORMATION

Prepared by	D. Heynderickx
Contributors	
Reference	SEPEM_ODI_TN2

CHANGE LOG

Issue	Date	Reason for change
1.0	30/12/2015	Description of data cleaning and gap filling.
1.1	19/11/2018	Data calibrations, merging and background subtraction.
1.2	28/11/2018	Comments from P. Jiggens (Section 6)

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1.1 APPLICABLE AND REFERENCE DOCUMENTS

1.1.1 APPLICABLE DOCUMENTS

[**AD 1**] Crosby, N. et al., "SEPEM Project Final Report," Ver 1.B, ESTEC Contract No.: 20162/06/NL/JD, 2011.

[**AD 2**] http://spitfire.estec.esa.int/pubtrac/ODI/wiki/OdiManual

[**AD 3**] Sandberg, I., "ESA SEPCALIB Project: Final Report," Ver. 1.2, ESA Contract No. 4000108377/13/NL/AK, 2014.

[**AD 4**] http://dev.sepem.oma.be/

[**AD 5**] Crosby, N. et al., "ESA SEPEM Project: Guidelines for models to be updated or included into the SEPEM system," Ver. 1.A, ESTEC Contract No.: 20162/06/NL/JD, 2011.

[**AD 6**] Sandberg, I. et al., "Cross calibration of NOAA GOES solar proton detectors using corrected NASA IMP-8/GME data," Geophysical Research Letters, 41, 2014.

[**AD 7**] Heynderickx, D.H. et al, "ESA IPRAM Project: Environment Specification," Ver. 1.2, ESA Contract No.: 4000106133/12/NL/AF, 2014.

[**AD 8**] "Statement of Work: Updating SOLPENCO2 and New Analysis on Downstream Fluence," European Space Agency, 2015.

[**AD 9**] ESA Contract No 4000115930/15/NL/HK.

1.1.2 REFERENCE DOCUMENTS

[**RD 1**] Crosby, N., "ESA SEPEM Project: Data Sets Descriptions," Ver. 0.A, ESTEC Contract No.: 20162/06/NL/JD, 2011.

[**RD 2**] Heynderickx, D.H., "IPRAM Project: DataSet Review," Ver. 1.4, ESA Contract No.: 4000106133/12/NL/AF, 2013.

[**RD 3**] Crosby, N.B, Heynderickx, D., Aran, A., Sanahuja, B., SEPEM Post-Maintenance Final Report, CCN-4 to ESA Contract No 4200020162, 2013.

[**RD 4**] Bonnevie, C., "ESA SEPEM Project Design Definition File," Ver 1.3, ESTEC Contract No.: 20162/06/NL/JD, 2011.

[**RD 5**] Jiggens, P.T.A. et al., "ESA SEPEM Project: Peak Flux and Fluence Model," IEEE Transactions on Nuclear Science, Vol. 59(4), 2012.

[**RD 6**] Aran, A. et al., "ESA SEPEM Project WP470 Report: Inclusion of SOLPENCO2 into SAT model. Events list out of 1.0 AU," Ver. 1.0, ESTEC Contract No.: 20162/06/NL/JD, 2011.

[**RD 7**] Tylka, A.J. & Dietrich, W.F., "A New and Comprehensive Analysis of Proton Spectra in Ground-Level Enhanced (GLE) Solar Particle Events," Proc. 31st International Cosmic Ray Conference, 2009.

[**RD 8**] https://www.spenvis.oma.be/

[**RD 9**] "Statement of Work: Improvement of Energetic Solar Heavy Ion Environment Models," European Space Agency, 2012.

[**RD 10**] GOES N DataBook, CDRL PM—1-03, Rev B, February 2005; http://goes.gsfc.nasa.gov/text/goes.databookn.html.

1.2 ACRONYMS AND ABBREVIATIONS

ACE	Advanced Composition Explorer
AD	Applicable Document
ASCII	American Standard Code for Information Interchange
BDDII	Burst Detector Dosimeter II
CDF	Common Data Format
ECSS	European Cooperation for Space Standardization
EPACT	Energetic Particle Acceleration, Composition, and Transport
EPEAD	Energetic Proton, Electron and Alpha Detector
EPS	Energetic Particles Sensor
ERNE	Energetic and Relativistic Nuclei and Electron
ESA	European Space Agency
ESHIEM	Improvement of Energetic Solar Heavy Ion Environment Models
FITS	Flexible Image Transport System
GEO	GEostationary Orbit
GME	Goddard Medium Energy
GOES	Geostationary Operational Environmental Satellite
GUI	Graphical User Interface
HEPAD	High Energy Proton and Alpha Detector
HDF	Hierarchical Data Format
IDL	Interactive Data Language
IMP	Interplanetary Monitoring Platform
LEMT	Low Energy Matrix Telescopes
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NetCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
ODI	Open Data Interface
RD	Reference Document
SEM	Space Environment Monitor
SEP	Solar Energetic Particle
SEPEM	Solar Energetic Particle Environment Modelling
SIS	Solar Isotope Spectrometer
SMS	Synchronous Meteorological Satellites
SoW	Statement of Work
SPE	Solar Particle Event
SQL	Structured Query Language
TN	Technical Note

2 INTRODUCTION

This document is the *SEPEM Data and System Updates* document, Technical Note 2 for the *ODI Integration in SEPEM*, ESA Contract No 4000115930/15/NL/HK.

2.1 CONTEXT

During the SEPEM contract [AD 1], a reference SPE proton dataset was constructed and made available on the SEPEM server [AD 4]. One of the tasks in this project is updating the existing reference proton dataset with more recent and also historical GOES/SEM data, which is the subject of this TN. The outline of this document is as follows:

1. Description of the datasets used (Section 3)
2. Data cleaning and gap filling procedures (Section 4)
3. Cross calibrations of the cleaned datasets (Section 5)
4. Dataset merging (Section 6)
5. Background subtraction (Section 7)

2.2 DATASET CHARACTERISTICS

Long term H measurements are available from the IMP8/GME and GOES/SEM/EPS series spacecraft instruments. New and old (prior to 1986) GOES data were processed to update and extend the SEPEM reference H dataset. The datasets were downloaded from internet data stores and ingested in the SEPEM database.

2.3 DATA CLEANING AND GAP FILLING

The GOES/EPS H data were manually checked for data records that exhibit spikes, saturation or any other defects that can be identified unambiguously. These values were replaced by fill values in the SEPEM database, and then gap filled using the SEPEM tools available on the server.

2.4 CROSS CALIBRATIONS OF H DATA

The EPS instruments deployed on the GOES spacecraft are monitor type instruments with poorly defined energy channels and have not been rigorously calibrated. During the SEPEM contract [AD 1], the EPS proton data were cross calibrated with the GME data, which are of science quality (after removal of bad data records).

More recently, a new calibration algorithm was developed [AD 3], which, instead of calibrating the GOES flux values, re-defines the energy bin limits of the GOES energy channels by finding a best fit solution to interpolated IMP/GME data. This method was applied to the whole GOES H dataset, including the data already present in the previous version of the reference dataset.

2.5 DATASET MERGING

Once the GOES/EPS datasets were cleaned and cross calibrated, they were re-binned to the SEPEM reference energy channels. The successive GOES spacecraft datasets were then merged into a single contiguous reference H dataset.

2.6 Background subtraction

The GOES/EPS instruments do not have active shielding, which implies that contamination of the measured H count rates by penetrating cosmic ray particles cannot be avoided. In addition, the detectors exhibit an inherent (thermal) noise level which further affects the count rates, especially for the highest energies.

In order to remove the background signal, a first order subtraction algorithm was applied to the combined, merged dataset.

3 GOES/EPS H DATASET CHARACTERISTICS

The Geostationary Operational Environmental Satellites (GOES) program, begun in 1974, is a program of the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce. GOES spacecraft operate as a two-satellite constellation in geosynchronous orbit above the equator and observe 60% of the Earth. Their instrument complement includes a suite of Space Environment Monitoring (SEM) instruments, which in turn includes Energetic Particles Sensors (EPS). A detailed description of the GOES programme and the SEM instruments can be found in [RD 2].

The EPS performs three integral measurements of electrons at >0.6, >2.0 and >4.0 MeV, a seven channel differential analysis of protons from 0.8 to 500 MeV (900 MeV for GOES13+), and a six channel differential analysis of alpha particles from 4 to 500 MeV. The EPS unit consists of a telescope subassembly, a dome subassembly and signal analyser unit/data processing unit. The EPS/HEPAD assembly for GOES13 is shown in Figure 1. Note that the GOES13-15 EPS assembly contains two EPEADs, one facing East and one facing West.

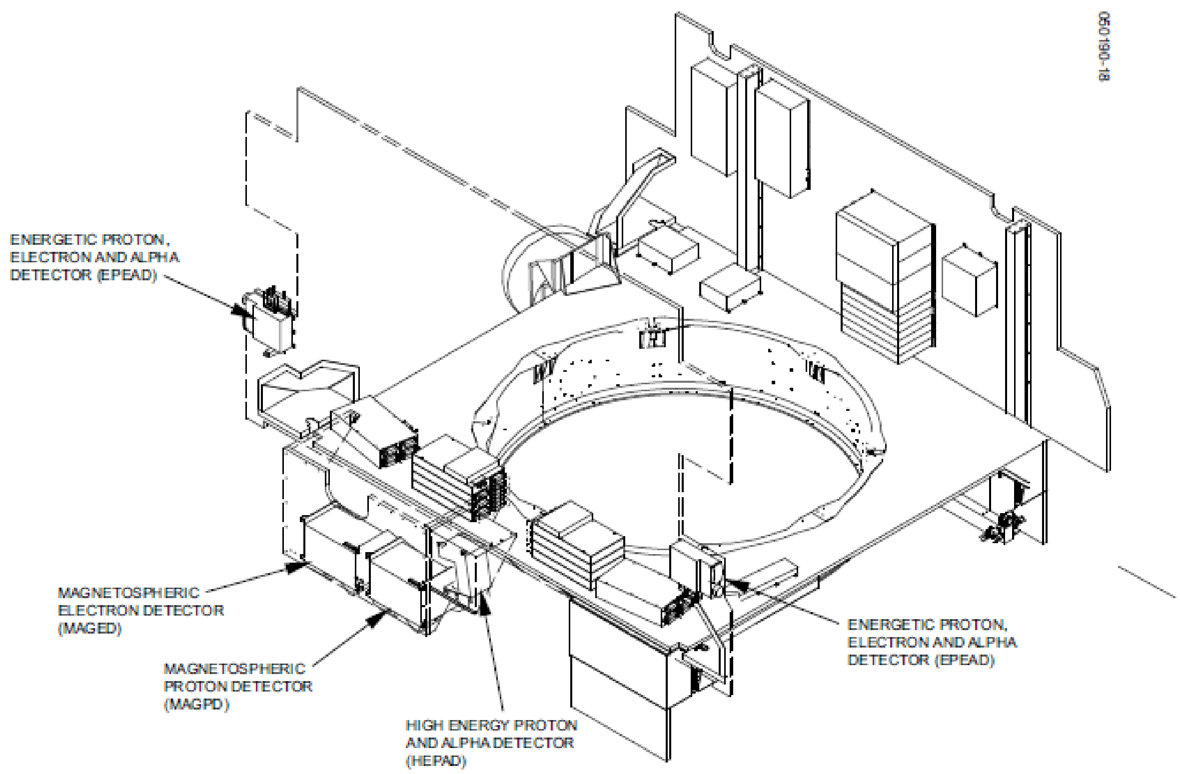

FIGURE 1 GOES13 EPS/HEPAD INSTRUMENT LOCATIONS (FROM [RD 10])

The EPS channel definitions have evolved over time with successive generations of GOES spacecraft. Table 1 summarizes the EPEAD H energy channels for each of them. The lowest energy channel P1 is not listed, as it is not used in SEPEM due to contamination by trapped protons.

TABLE 1 NOMINAL EPEAD H CHANNEL ENERGIES (MEV) FOR THE GOES SPACECRAFT USED IN THIS STUDY

Channel	SMS01-02 / GOES01	GOES02	GOES05-07	GOES08-12	GOES13-15
P2	4.0- 6.0	4.0- 8.0	4.2- 8.7	4.0- 9.0	4.2- 8.7
P3	6.0- 10.0	8.0- 16.0	8.7- 14.5	9.0- 15.0	8.7- 14.5
P4	18.0- 38.0	16.0- 36.0	15.0- 44.0	15.0- 40.0	15.0- 40.0
P5	40.0-500.0	36.0-500.0	39.0- 82.0	40.0- 80.0	38.0- 82.0
P6	84.0-150.0	80.0-215.0	84.0-200.0	80.0-165.0	84.0-200.0
P7	150.0-500.0	215.0-500.0	110.0-500.0	165.0-500.0	110.0-900.0

Data from the following GOES spacecraft were used in this study: 01, 02, 05, 07, 08, 11 and 13, as well as data from the precursor spacecraft SMS01-02. The 5 minute ASCII G data files for the GOES05-11 spacecraft were already ingested in the SEPEM database. The recent 5 minute NetCDF `epead_a16ew_5m` data files for GOES13 were downloaded from ftp://satdat.ngdc.noaa.gov/sem/goes/data/new_avg/ and converted to ASCII files using the IDL code developed during the SEPEM maintenance phase.

During the SEPEM maintenance phase [RD 3], the SMS and GOES FITS format files prior to 1986 were processed and converted into the same format as the 5 minute G and A files. The resulting G files were added to the SEPEM database.

4 Data cleaning and gap filling

The EPS H data do not suffer from saturation or dead time effects. Also, data gaps during SPEs are very rare and very short, and can be gap filled with the manual cleaning tool (with one or two exceptions during the earliest missions where the peak of a (small) event was missing, and GME data were used to fill the gap). During quiet periods, data coverage is intermittent, but there is sufficient coverage to reliable gap fill the background data, so that contiguous datasets can be constructed.

The GOES data do exhibit data spikes of varying magnitude. The older datasets are affected most, while in the GOES13 dataset, for instance, there are virtually no spikes. Figure 2 shows an example of a time period in the SMS01 dataset, manual cleaning and gap filling yields the time series shown in Figure 3. When longer time series are badly affected by spikes, the data from the secondary GOES satellite (and from IMP8/GME where available) are checked to ensure that there were no SPEs.

GOES13 suffered an outage on 22–30 May 2013. The H data for that period were patched with GOES15 data.

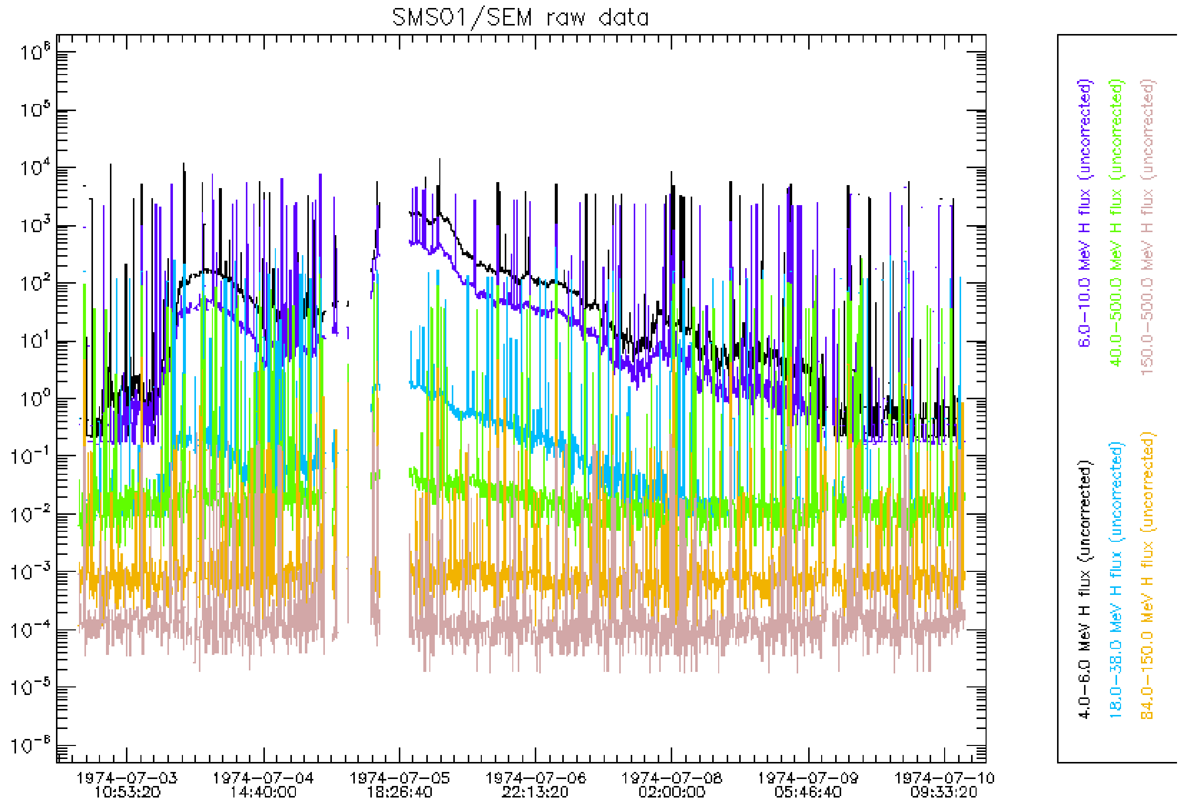

FIGURE 2 RAW SMS01 H DATA FOR THE JUL 1974 SPE

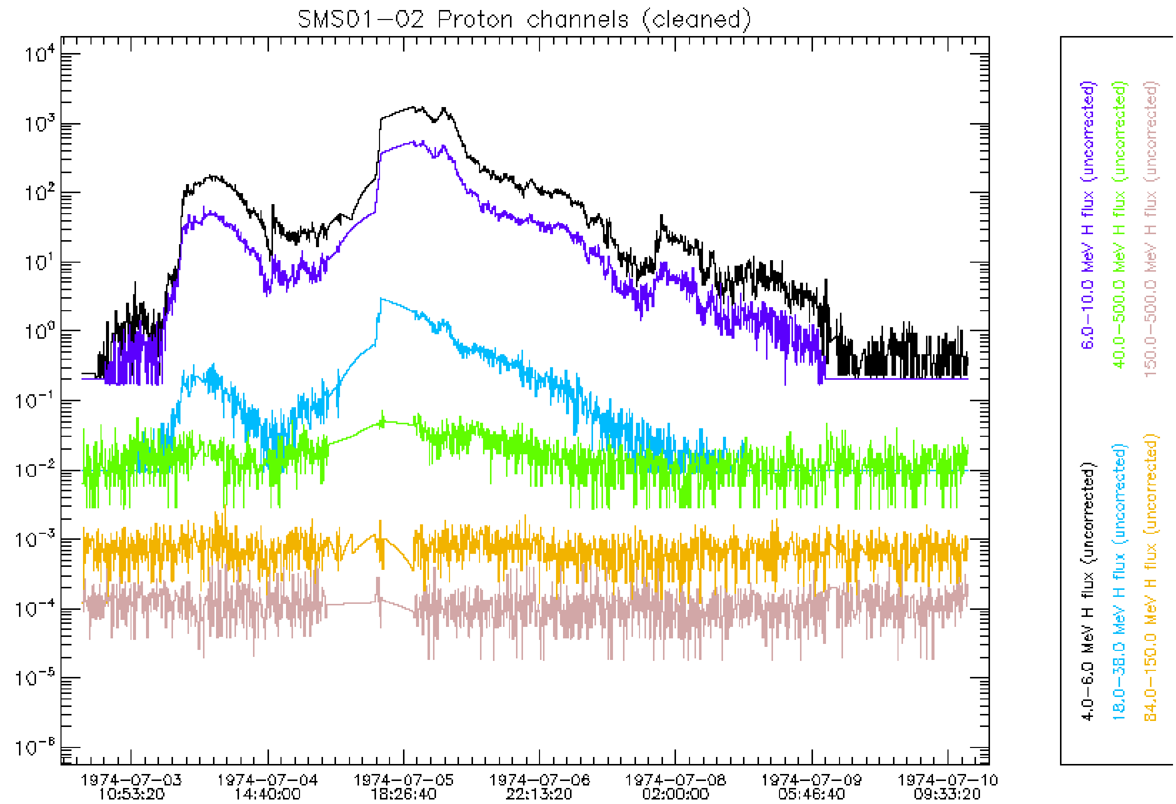

FIGURE 3 CLEANED SMS01 H DATA FOR THE JUL 1974 SPE

5 CROSS CALIBRATIONS OF H DATA

During the SEPEM project, the GOES H data were cross-calibrated with the IMP8/GME H data using linear regression relations between flux values with the same time stamps. The regression analysis was performed after re-binning the energy channels for the various datasets into the SEPEM reference energy channels.

In this project, a different approach is used for the H data. In the SEPCALIB project [AD 3], a method was developed to determine the “true” energy centroids for the GOES channels by minimising the variance with respect to the GME data, re-binned into a fine grid of channels. Using these energy values, copies of the GOES H datasets were made with the new channel definitions. These new tables were then re-binned in energy into the SEPEM reference energy channels, listed in Table 2.

TABLE 2 SEPEM H REFERENCE CHANNELS (MEV)

Channel	E_l	E_u	E_c
P1	5.000	7.231	6.013
P2	7.231	10.46	8.695
P3	10.46	15.12	12.57
P4	15.12	21.87	18.18
P5	21.87	31.62	26.30
P6	31.62	45.73	38.03
P7	45.73	66.13	54.99
P8	66.13	95.64	79.53
P9	95.64	138.3	115.0
P10	138.3	200.0	166.3
P11	200.0	289.2	240.5

Due to the sparseness of the GME data, the SEPCALIB procedure proved problematic for a number of channels where almost no fluxes matching with GOES data were found above background levels for individual datasets. Therefore, it was decided to combine the fluxes from the earliest individual datasets into two pairs: SMS1,2 and GOES01,02. In addition, in order to match the 30 min time resolution of the IMP-8/GME data, the GOES data were averaged over 30 min time bins.

Figure 4 – Figure 9 show the SEPCALIB analysis summaries for the 6 channels of the combined SMS1,2 dataset, Figure 10 – Figure 14 for the combined GOES01,02 dataset (channel P4 is corrupted), and Figure 15 – Figure 20, Figure 21 – Figure 26, Figure 27 – Figure 32, Figure 33 – Figure 38, for the GOES05, GOES07, GOES08, and GOES11 datasets, respectively. The red lines in the bottom panels represent the relation log Y = log X, the green curves represent the linear fit shown in the captions.

The total mission fluence spectra for the combined datasets are shown in Figure 39 – Figure 44. The black lines and symbols represent the uncalibrated fluences, the red lines and symbols are the same fluences at the new energies obtained with the SEPCALIB procedure. Figure 45 – Figure 50 show the SEPCALIB goodness of fit parameter as a function of energy for the respective datasets.

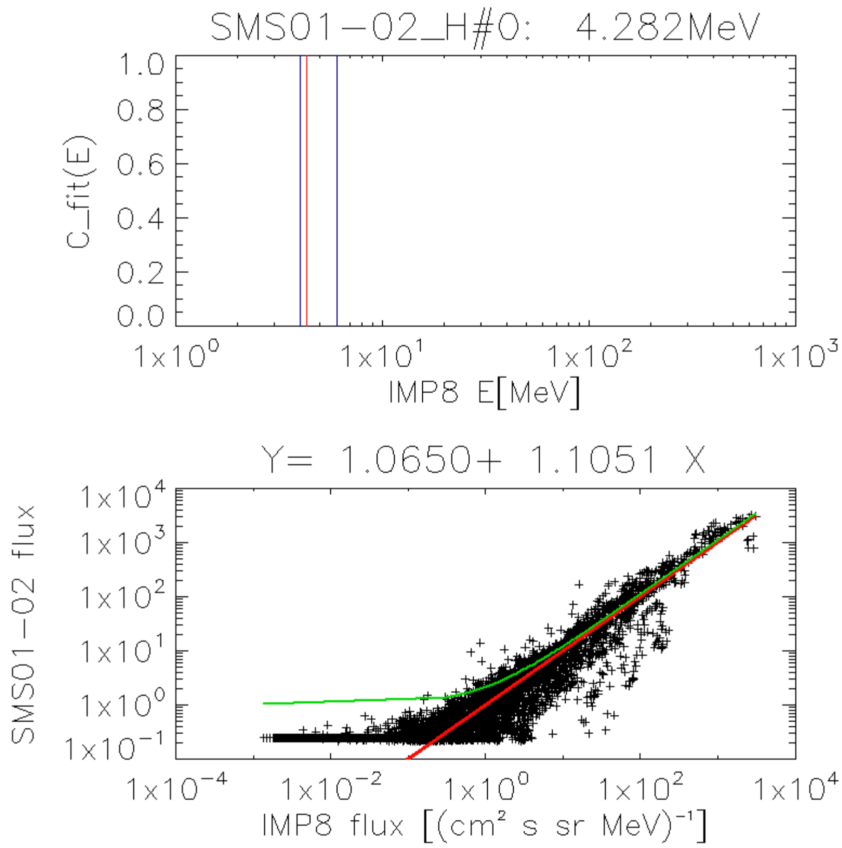

FIGURE 4 SEPCALIB ANALYSIS FOR SMS1,2 CHANNEL P2

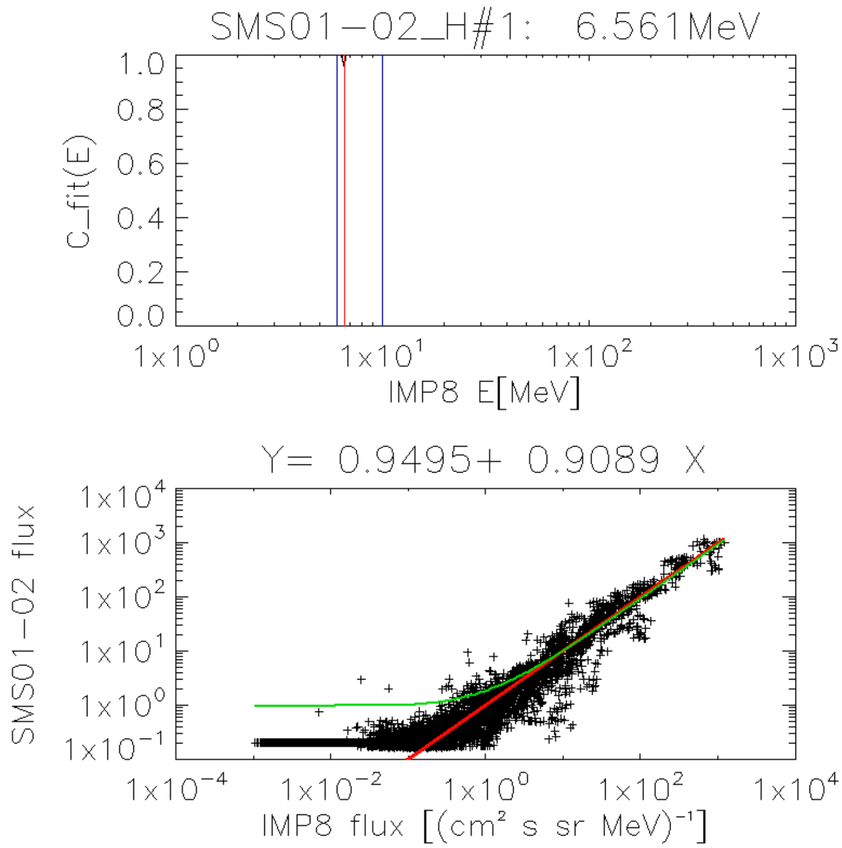

FIGURE 5 SEPCALIB ANALYSIS FOR SMS1,2 CHANNEL P3

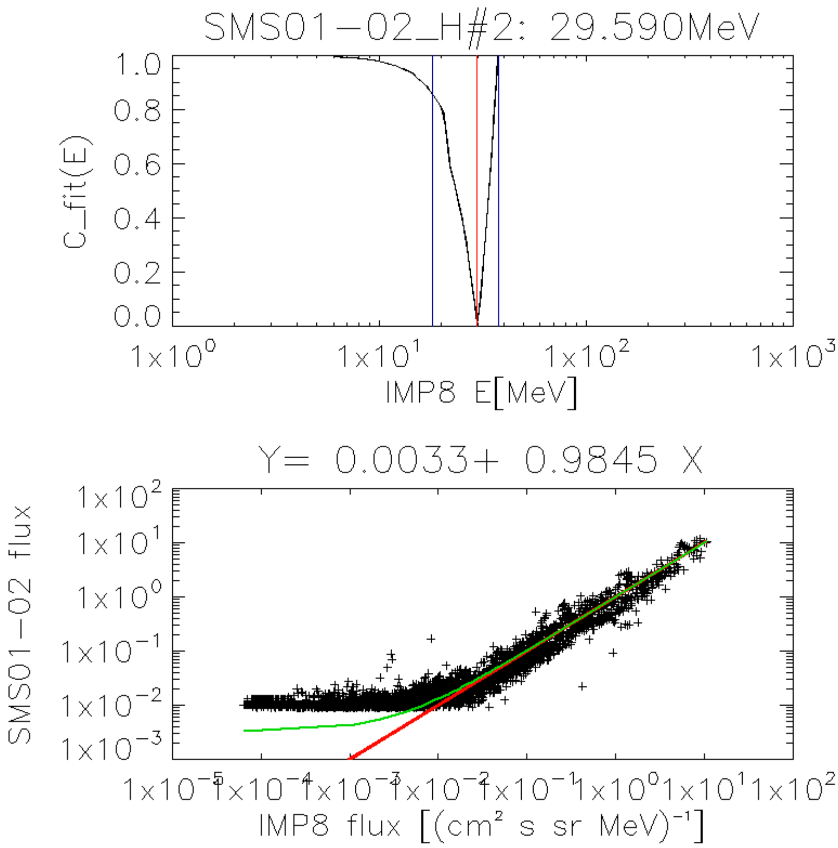

FIGURE 6 SEPCALIB ANALYSIS FOR SMS1,2 CHANNEL P4

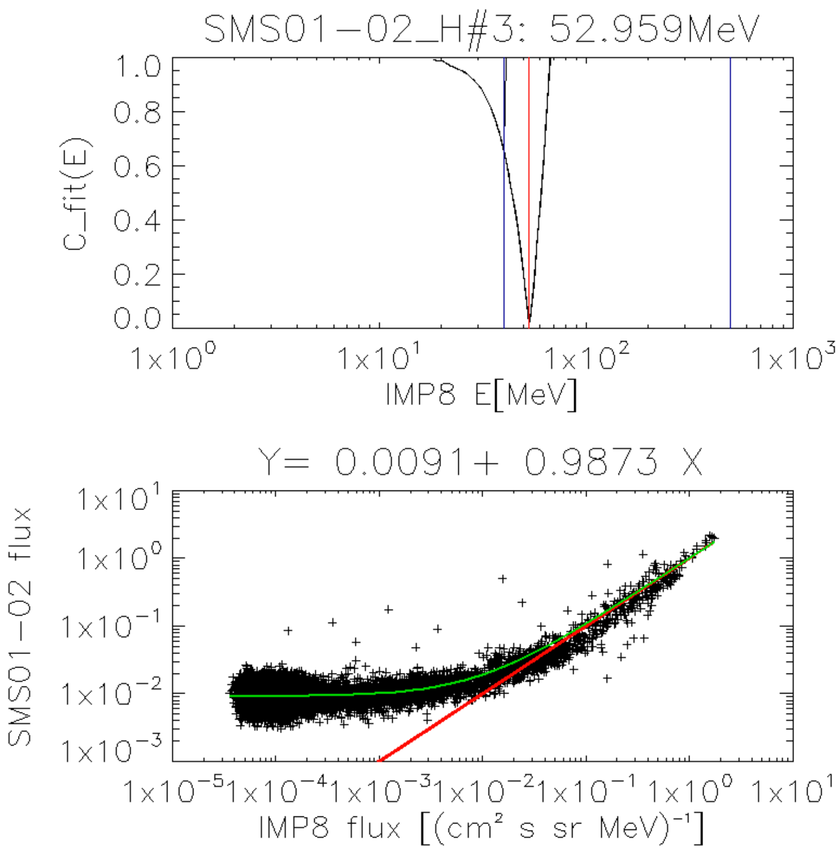

FIGURE 7 SEPCALIB ANALYSIS FOR SMS1,2 CHANNEL P5

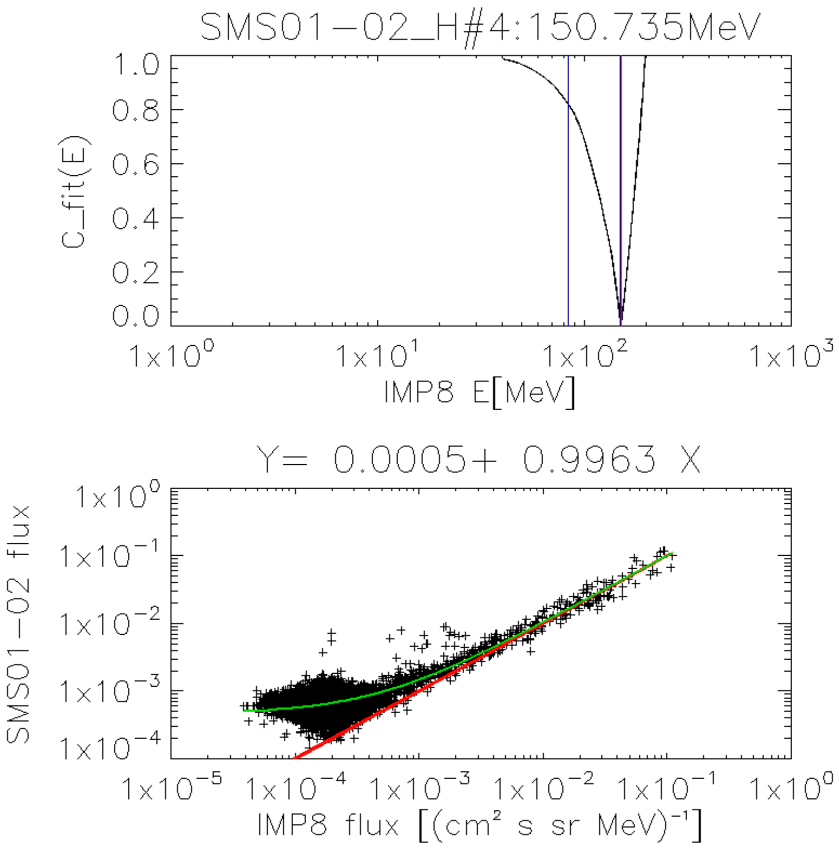

FIGURE 8 SEPCALIB ANALYSIS FOR SMS1,2 CHANNEL P6

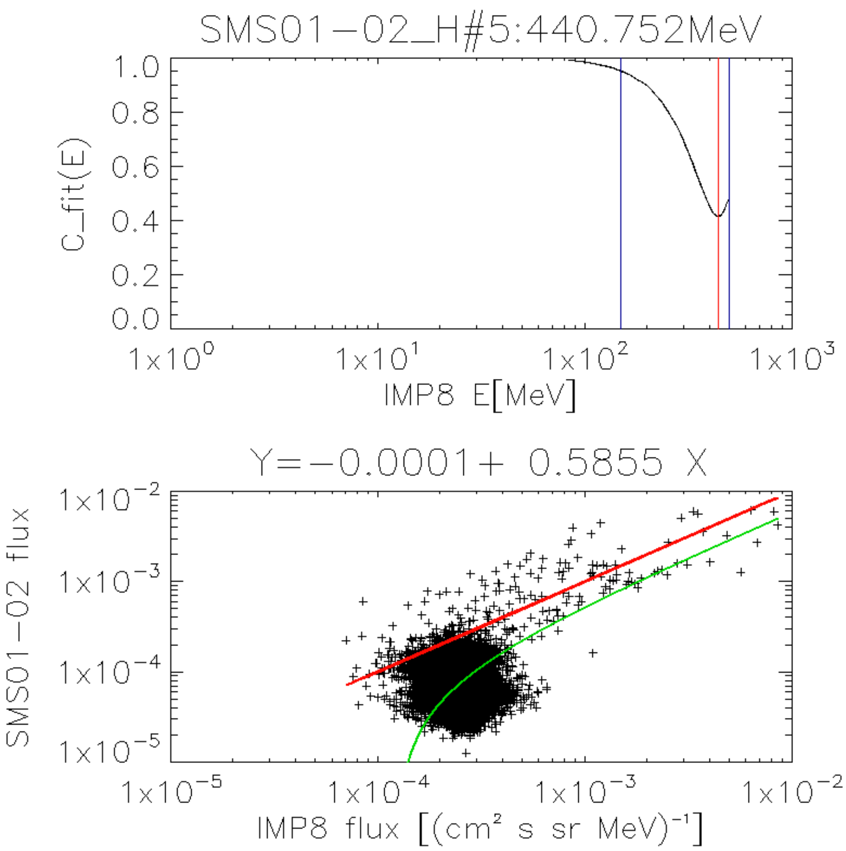

FIGURE 9 SEPCALIB ANALYSIS FOR SMS1,2 CHANNEL P7

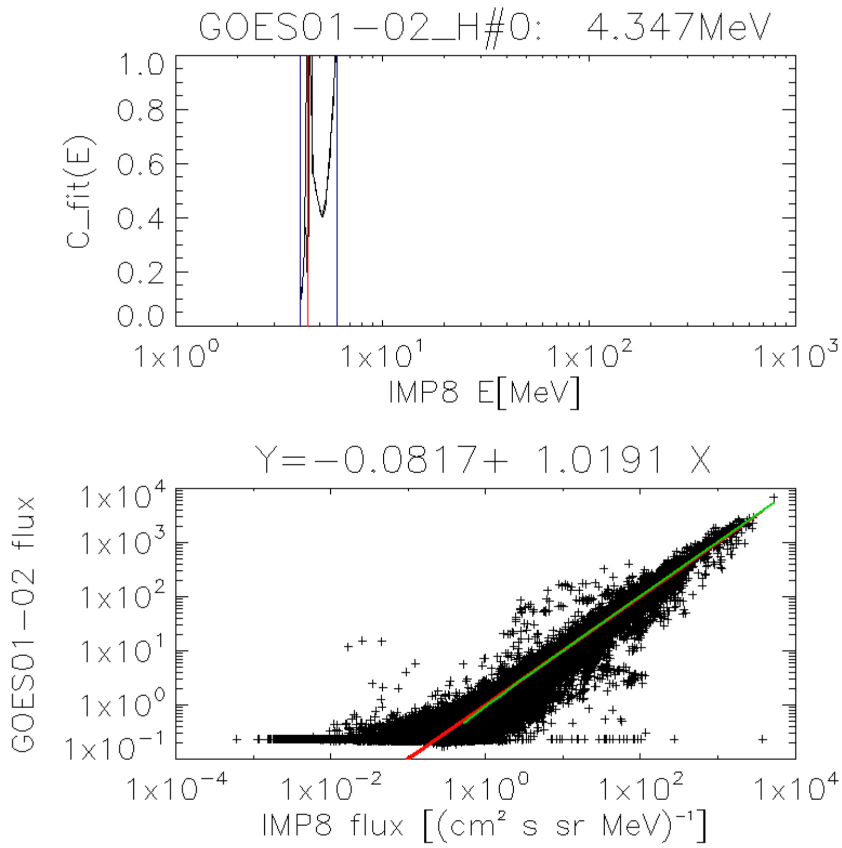

FIGURE 10 SEPCALIB ANALYSIS FOR GOES01,02 CHANNEL P2

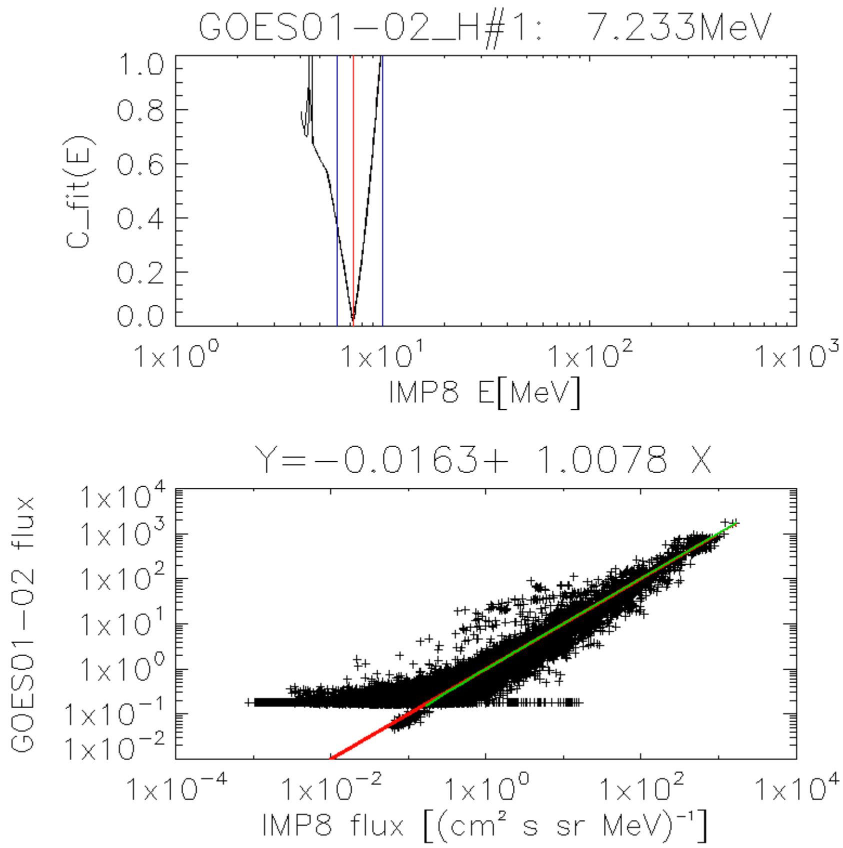

FIGURE 11 SEPCALIB ANALYSIS FOR GOES01,02 CHANNEL P3

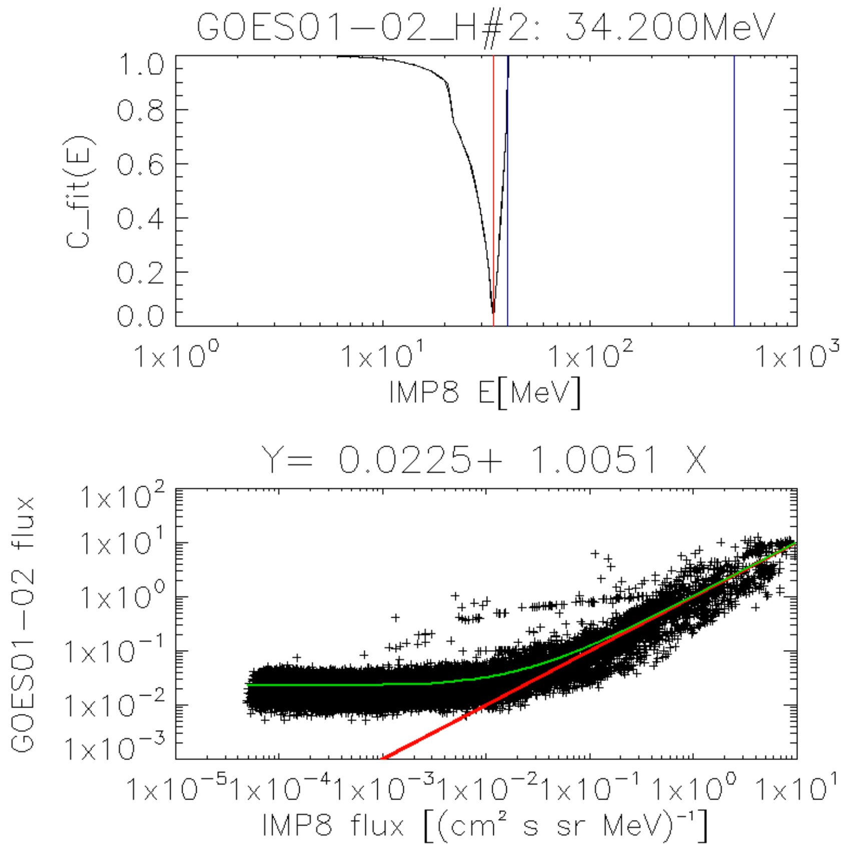

FIGURE 12 SEPCALIB ANALYSIS FOR GOES01,02 CHANNEL P5

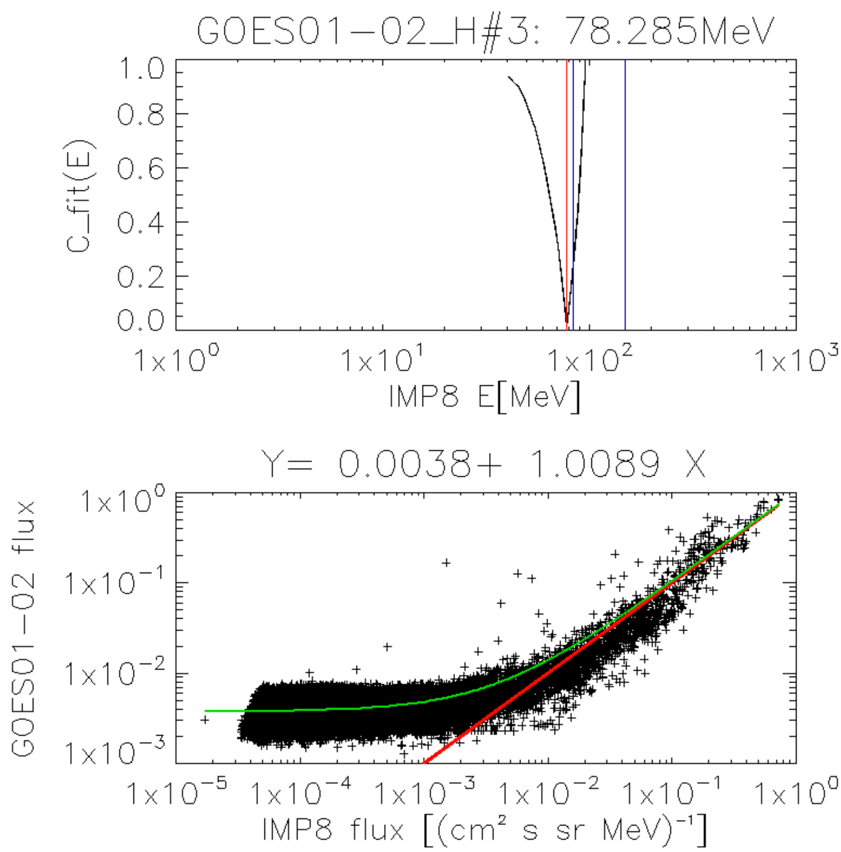

FIGURE 13 SEPCALIB ANALYSIS FOR GOES01,02 CHANNEL P6

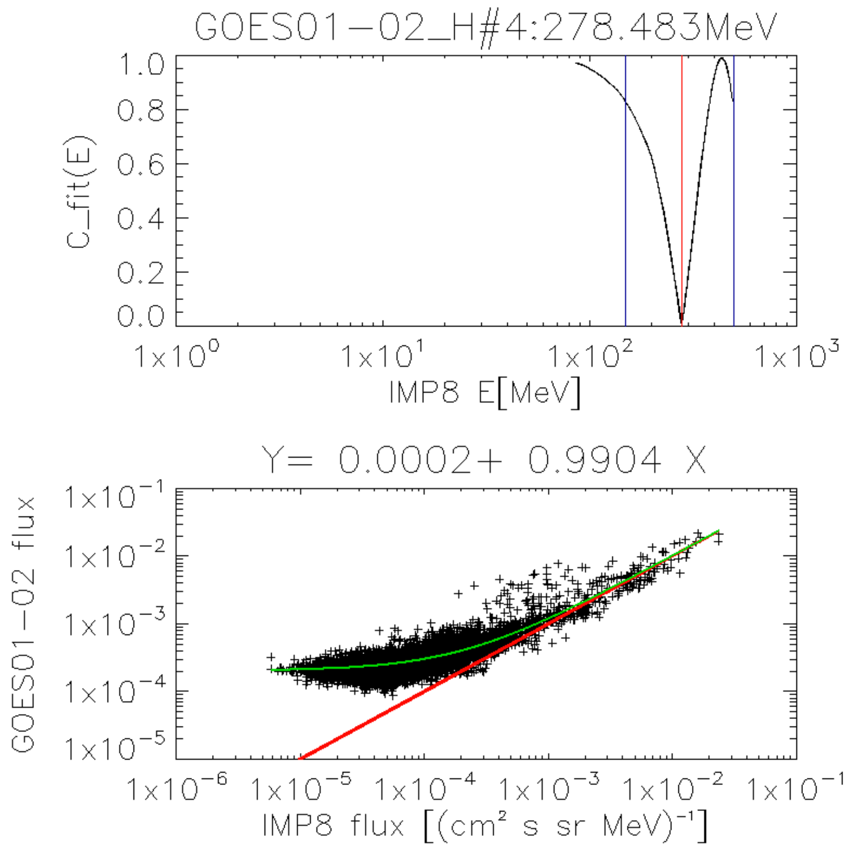

FIGURE 14 SEPCALIB ANALYSIS FOR GOES01,02 CHANNEL P7

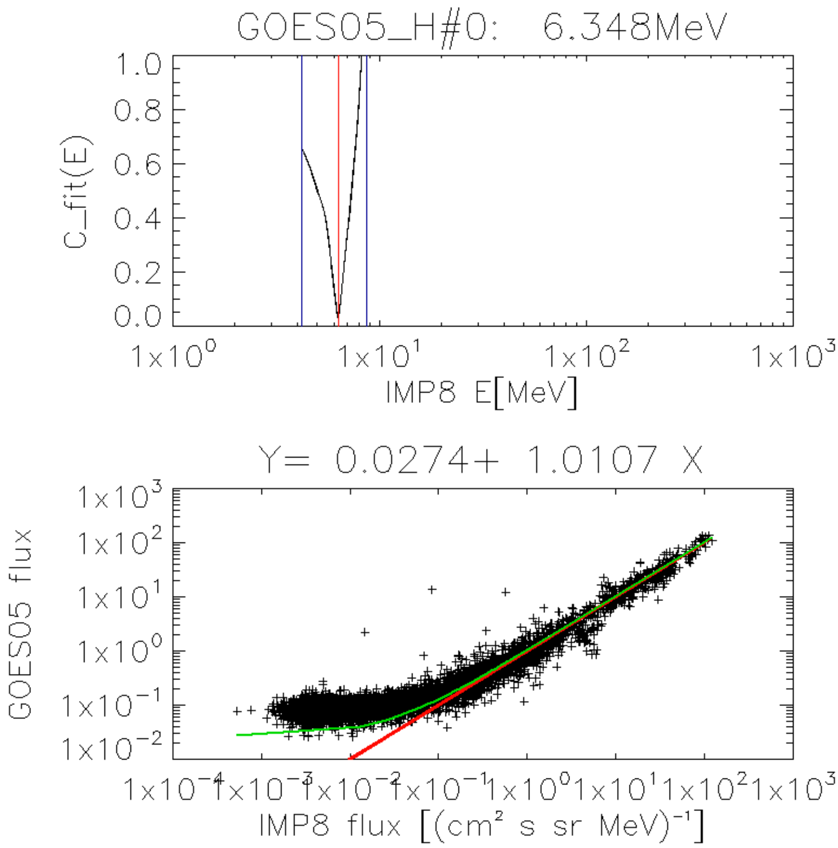

FIGURE 15 SEPCALIB ANALSIS FOR GOES05 CHANNEL P2

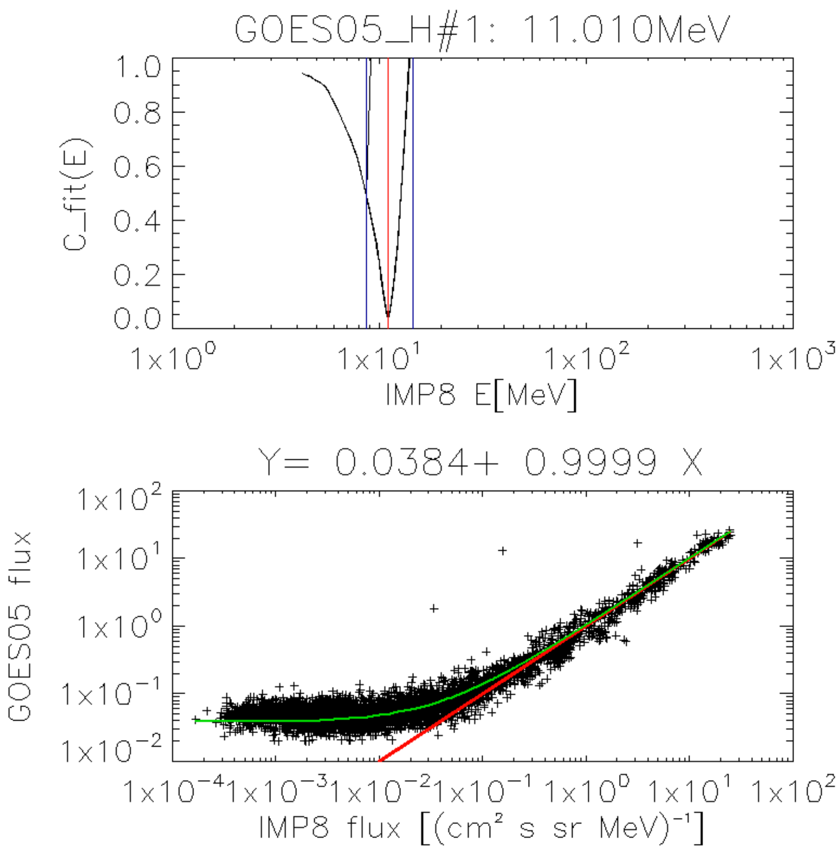

FIGURE 16 SEPCALIB ANALSIS FOR GOES05 CHANNEL P3

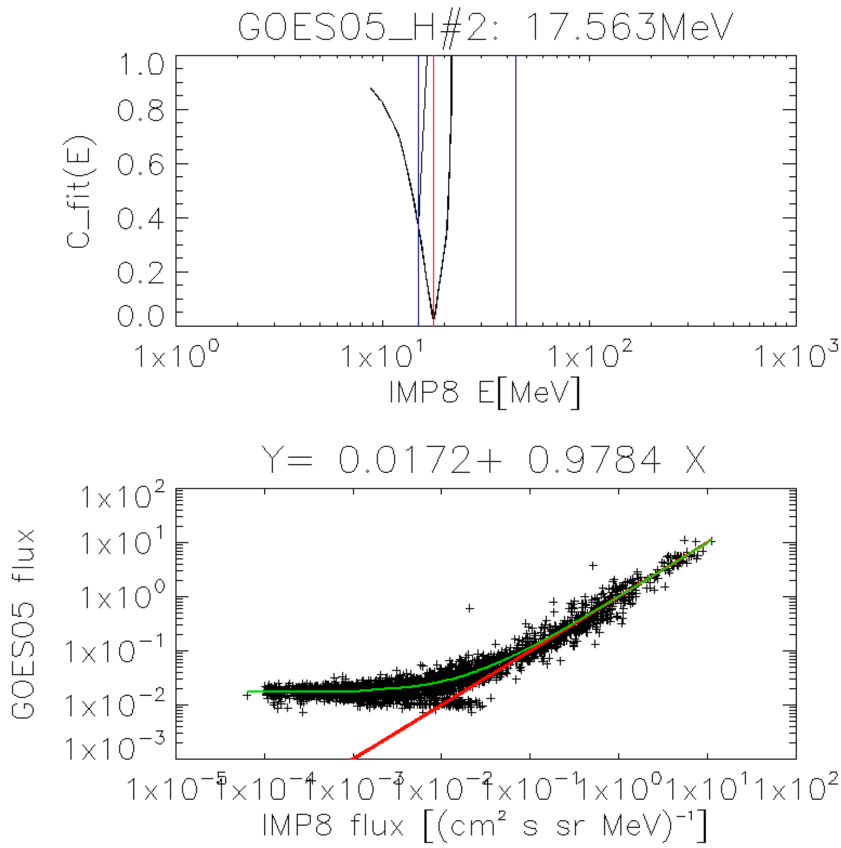

FIGURE 17 SEPCALIB ANALSIS FOR GOES05 CHANNEL P4

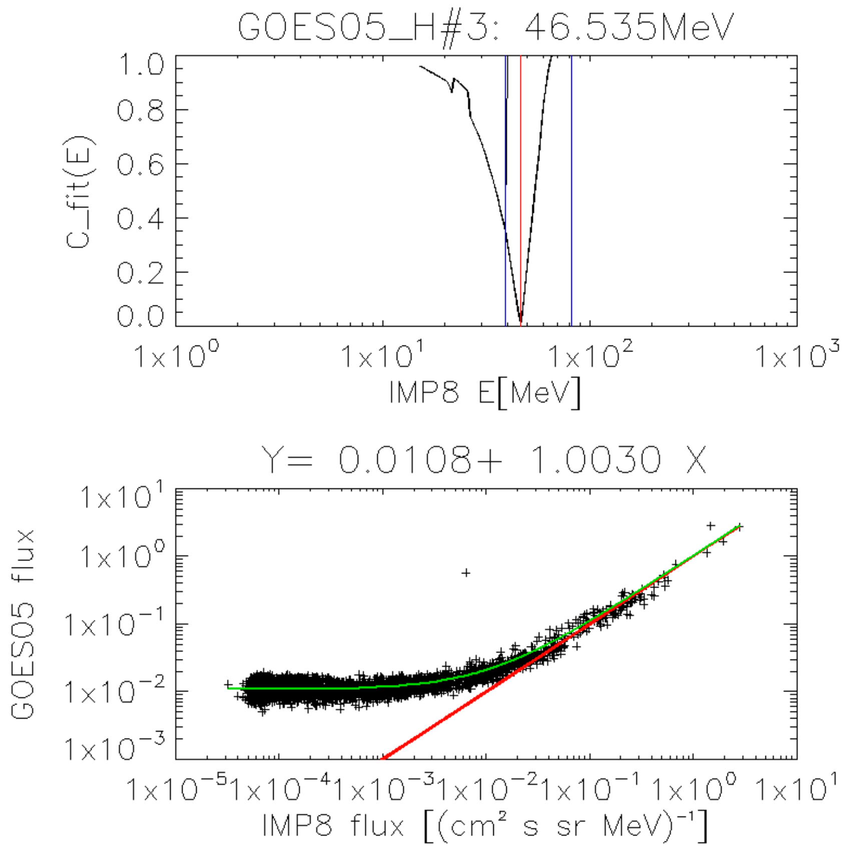

FIGURE 18 SEPCALIB ANALSIS FOR GOES05 CHANNEL P5

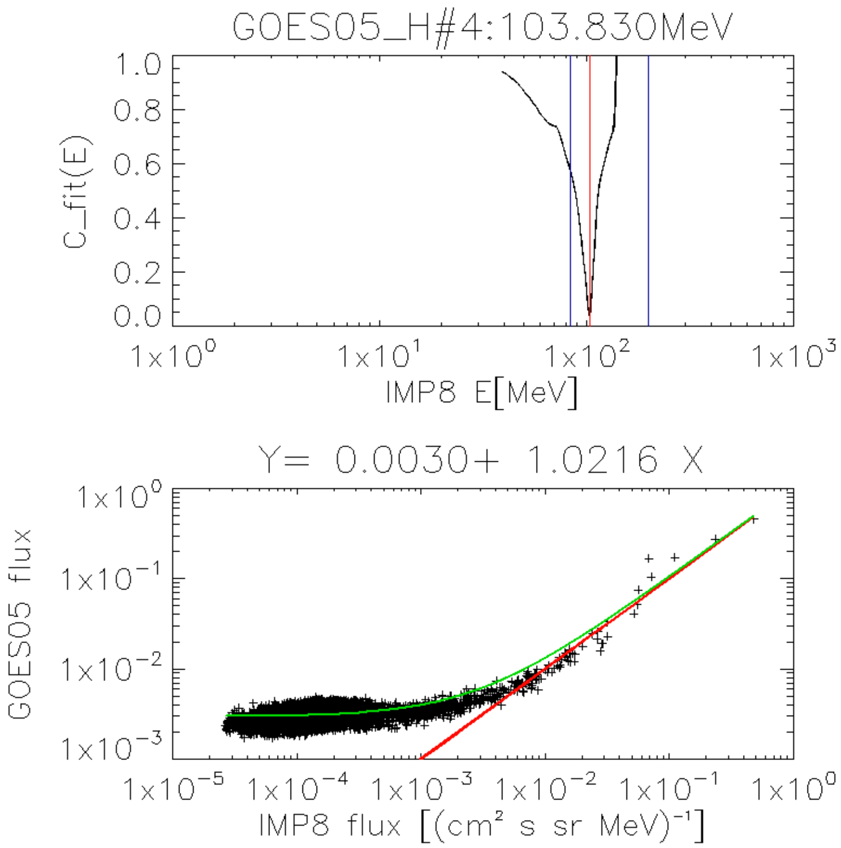

FIGURE 19 SEPCALIB ANALSIS FOR GOES05 CHANNEL P6

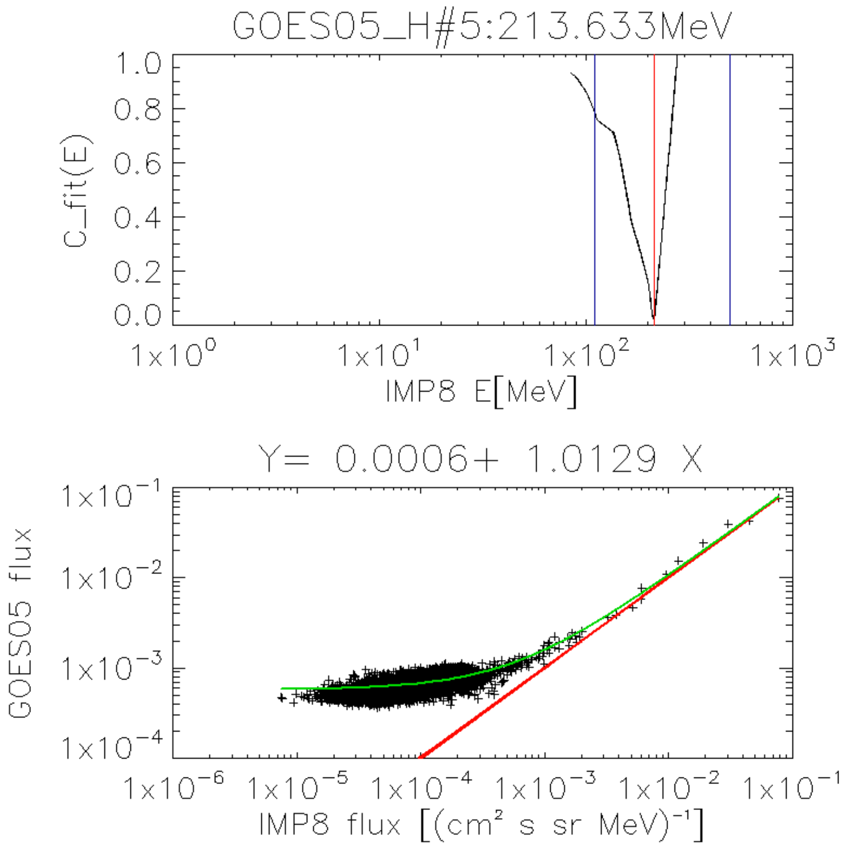

FIGURE 20 SEPCALIB ANALSIS FOR GOES05 CHANNEL P7

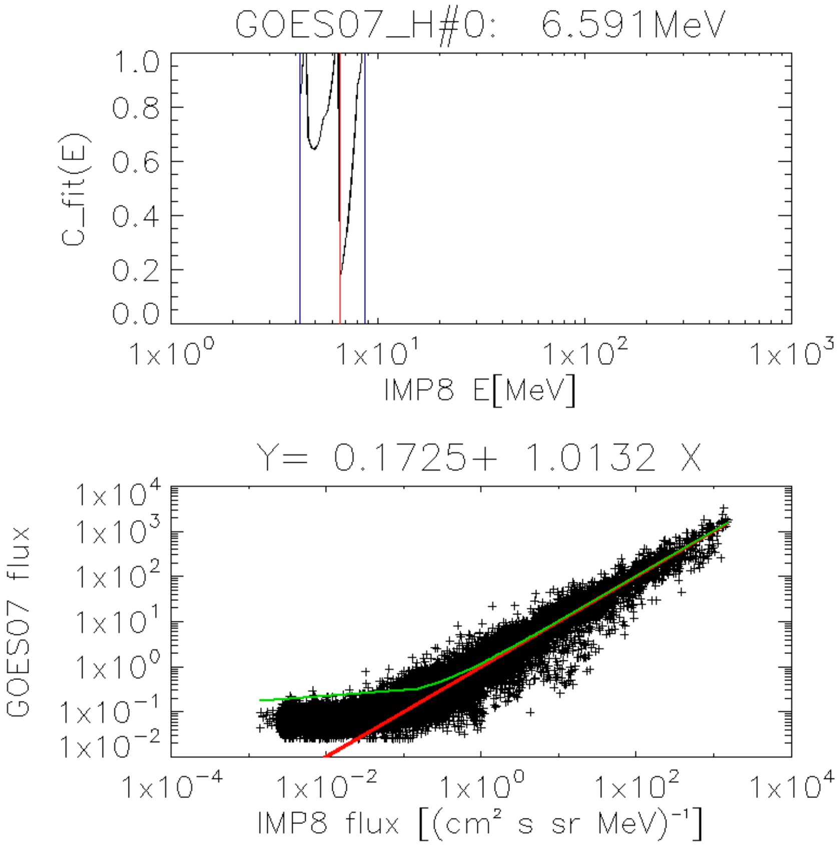

FIGURE 21 SEPCALIB ANALSIS FOR GOES07 CHANNEL P2

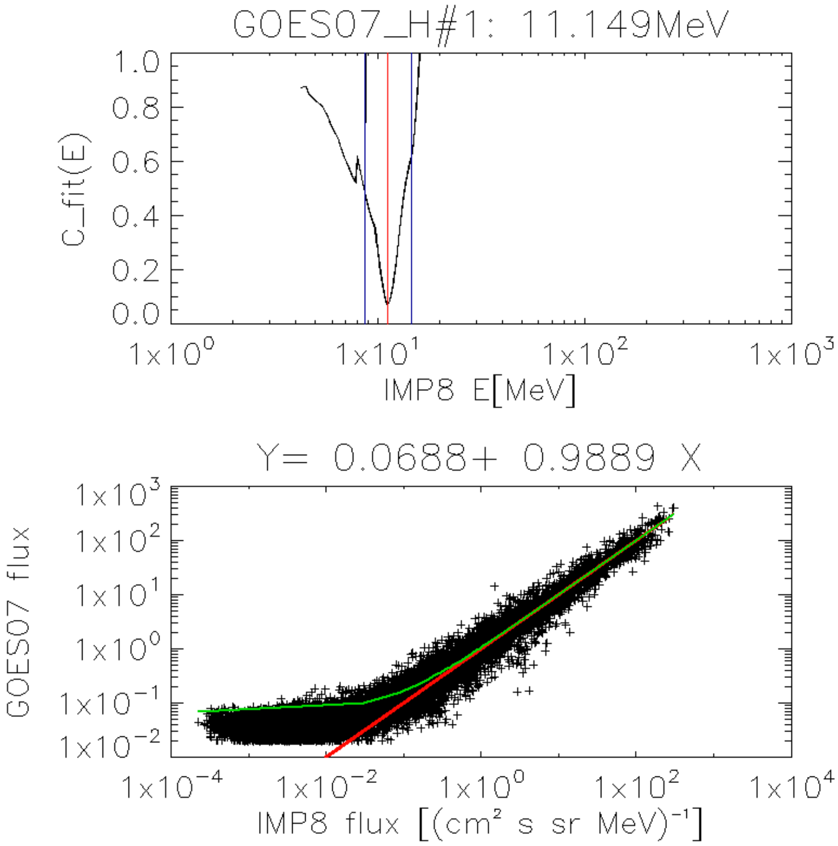

FIGURE 22 SEPCALIB ANALSIS FOR GOES07 CHANNEL P3

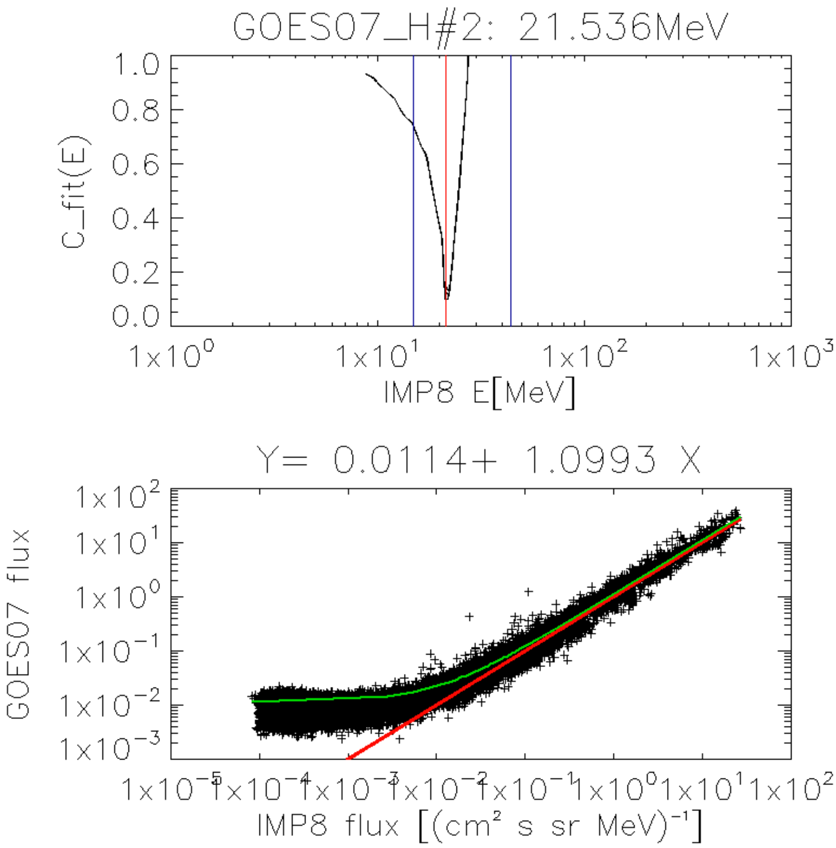

FIGURE 23 SEPCALIB ANALSIS FOR GOES07 CHANNEL P4

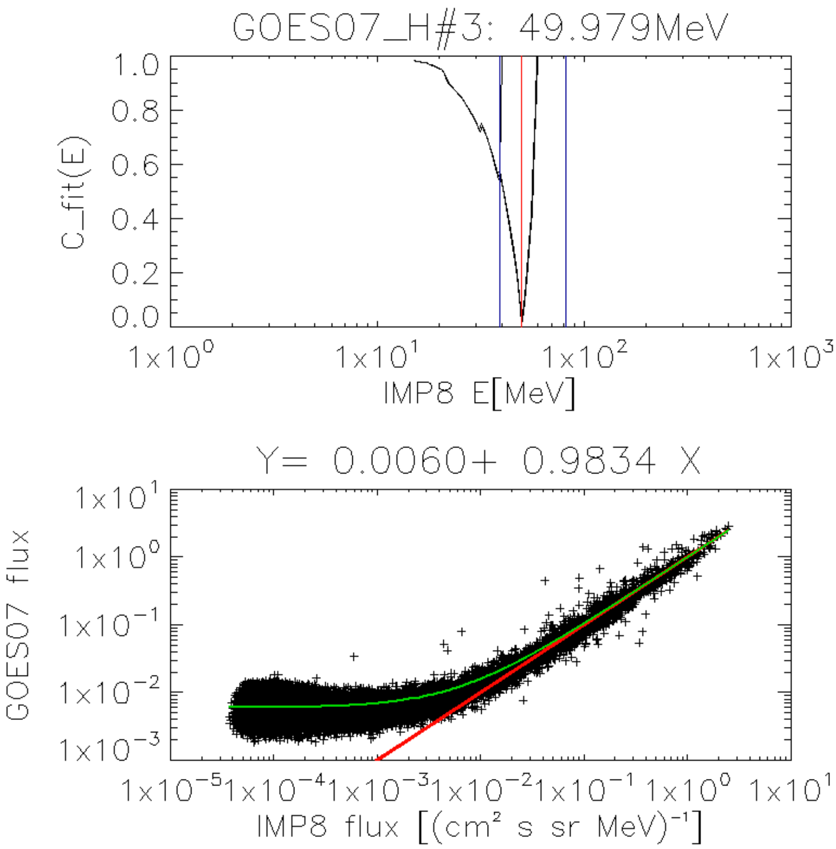

FIGURE 24 SEPCALIB ANALSIS FOR GOES07 CHANNEL P5

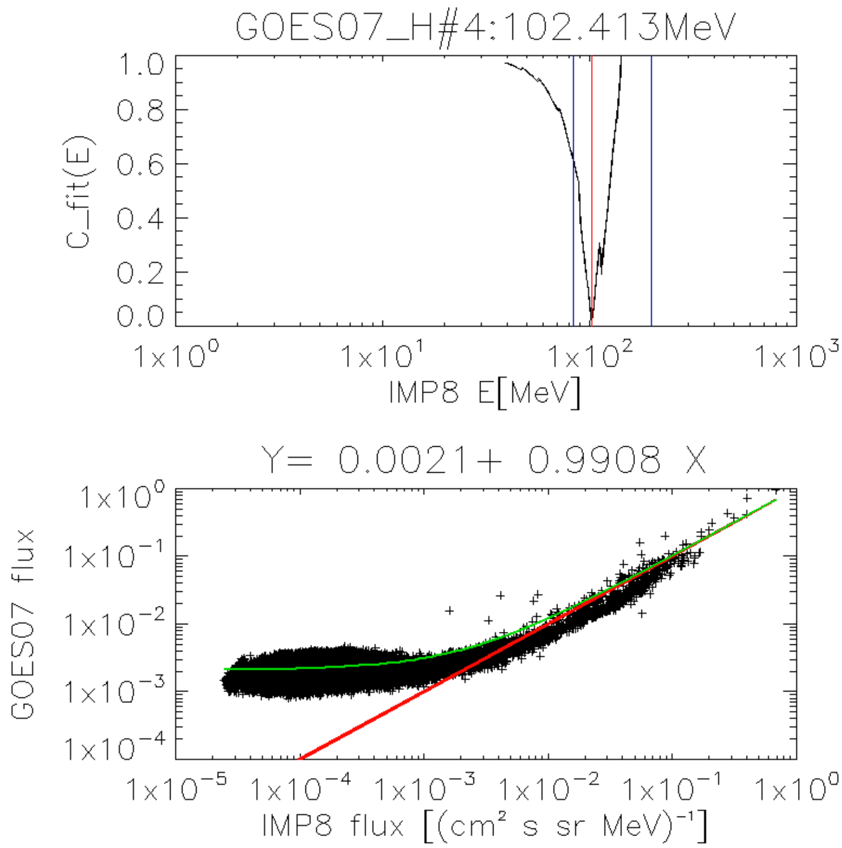

FIGURE 25 SEPCALIB ANALSIS FOR GOES07 CHANNEL P6

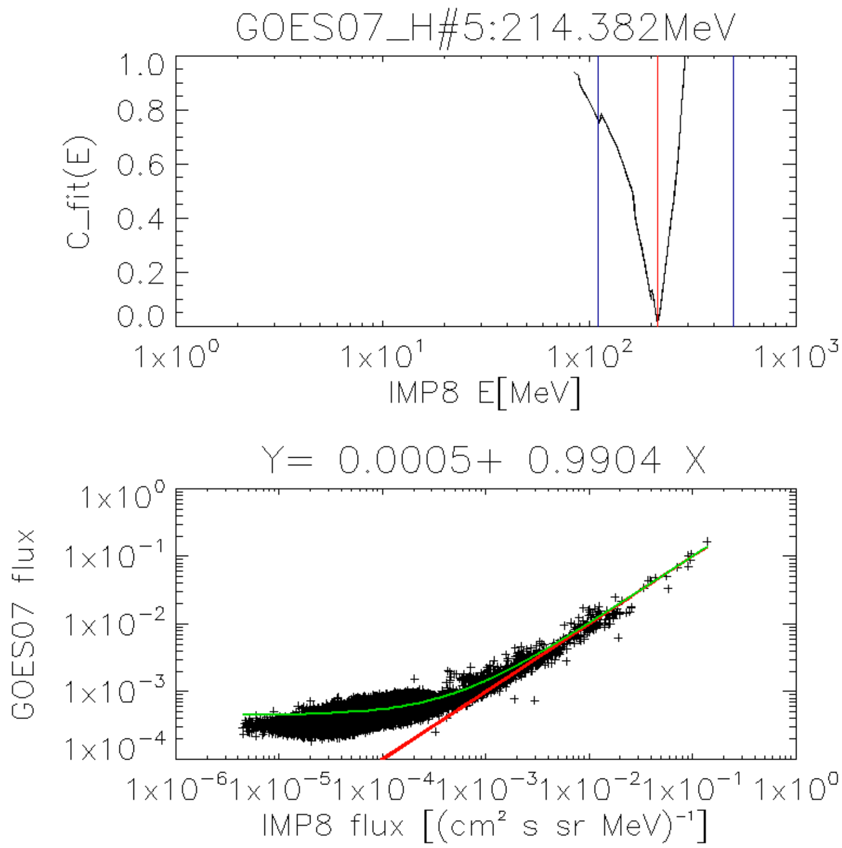

FIGURE 26 SEPCALIB ANALSIS FOR GOES07 CHANNEL P7

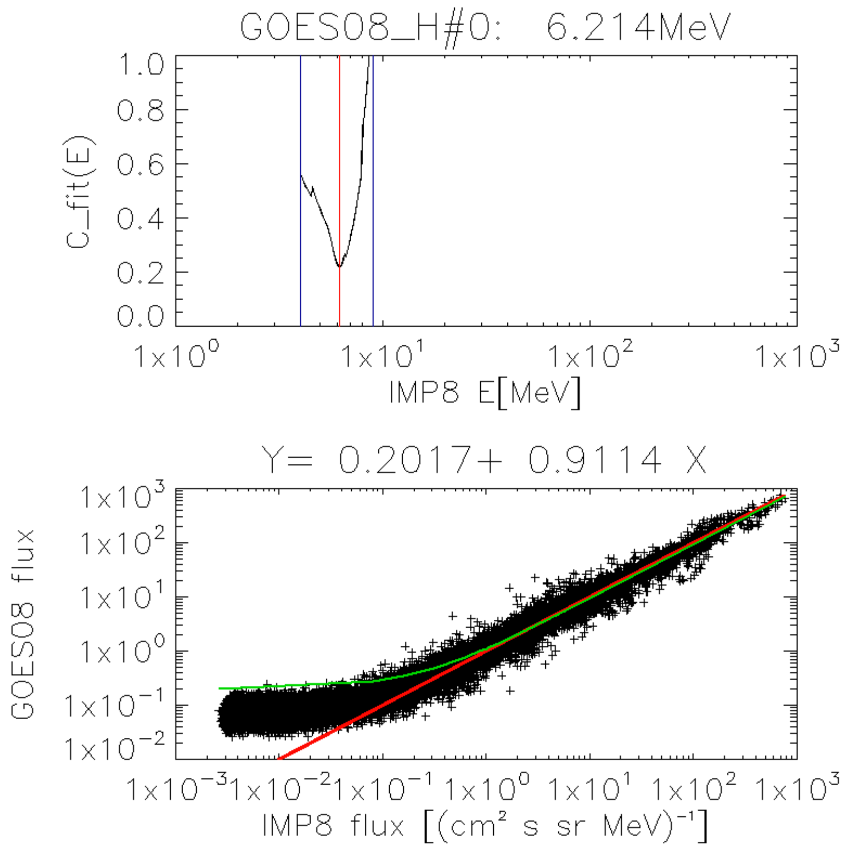

FIGURE 27 SEPCALIB ANALSIS FOR GOES08 CHANNEL P2

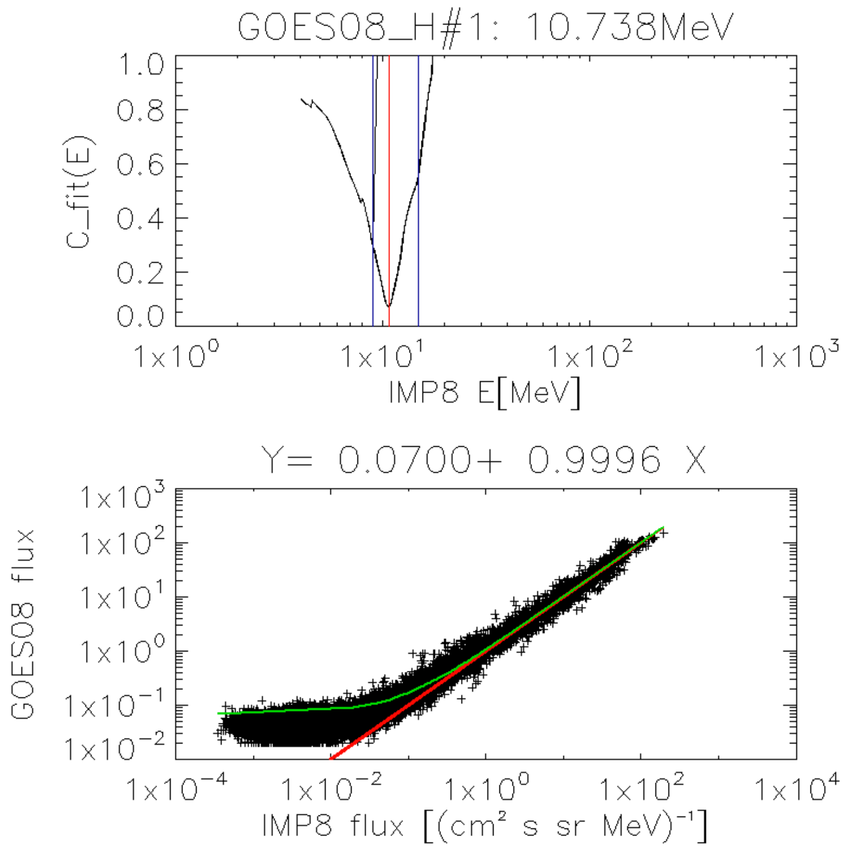

FIGURE 28 SEPCALIB ANALSIS FOR GOES08 CHANNEL P3

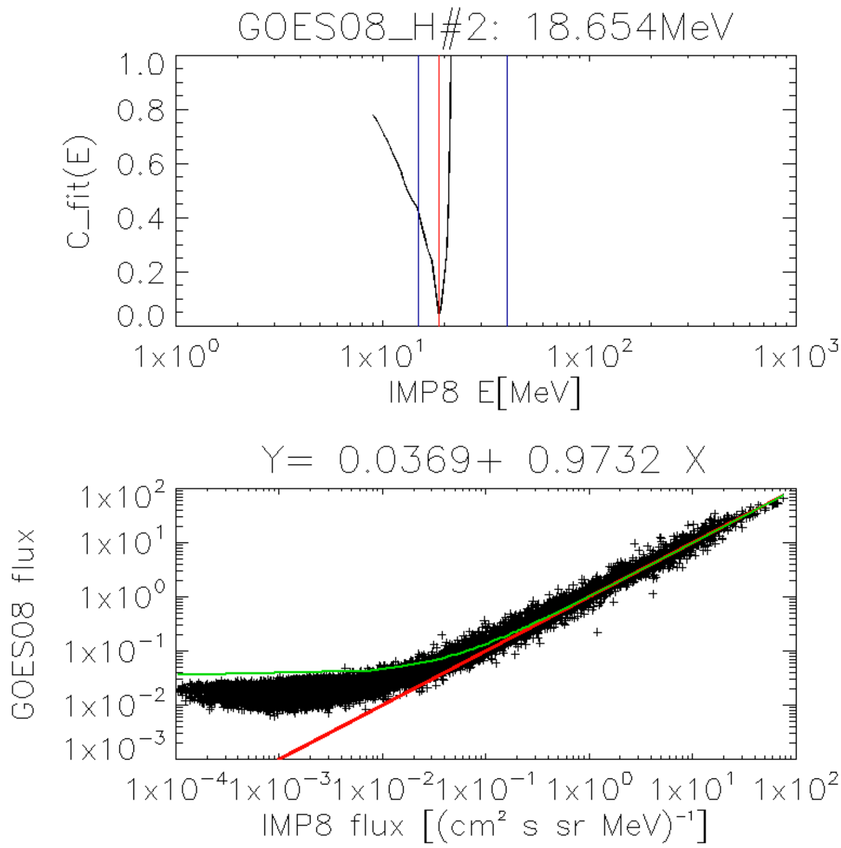

FIGURE 29 SEPCALIB ANALSIS FOR GOES08 CHANNEL P4

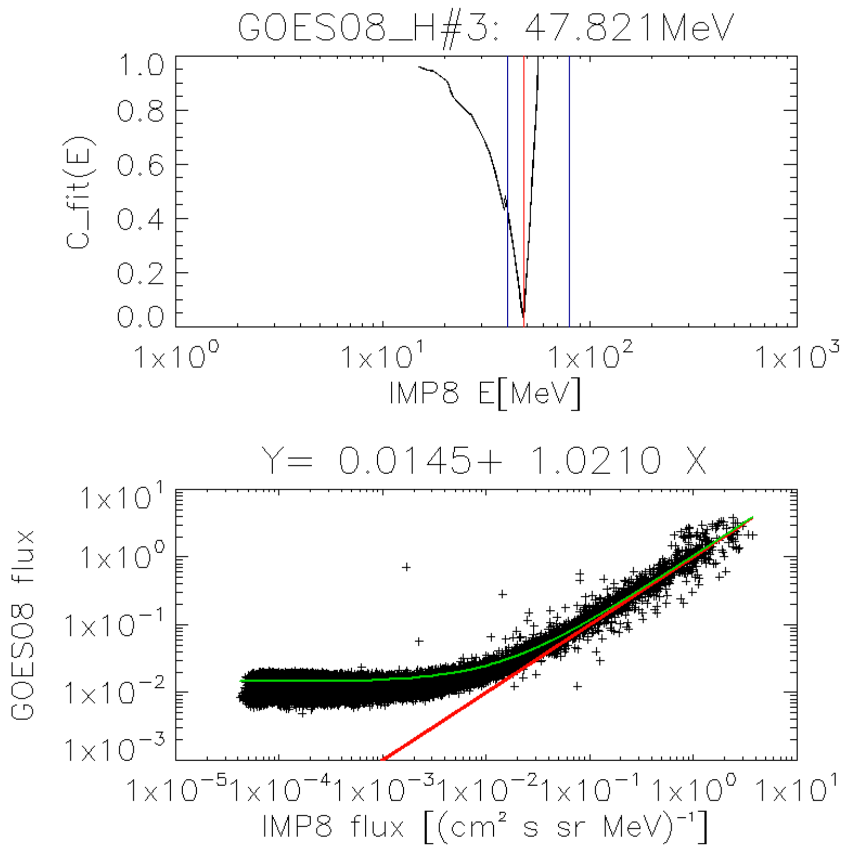

FIGURE 30 SEPCALIB ANALSIS FOR GOES08 CHANNEL P5

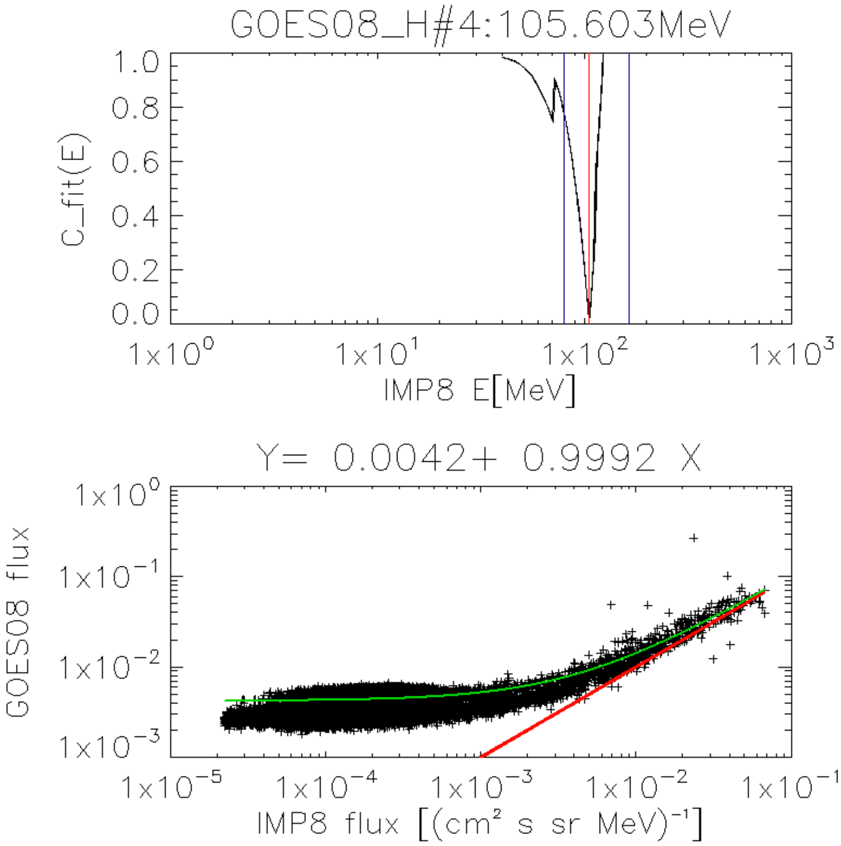

FIGURE 31 SEPCALIB ANALSIS FOR GOES08 CHANNEL P6

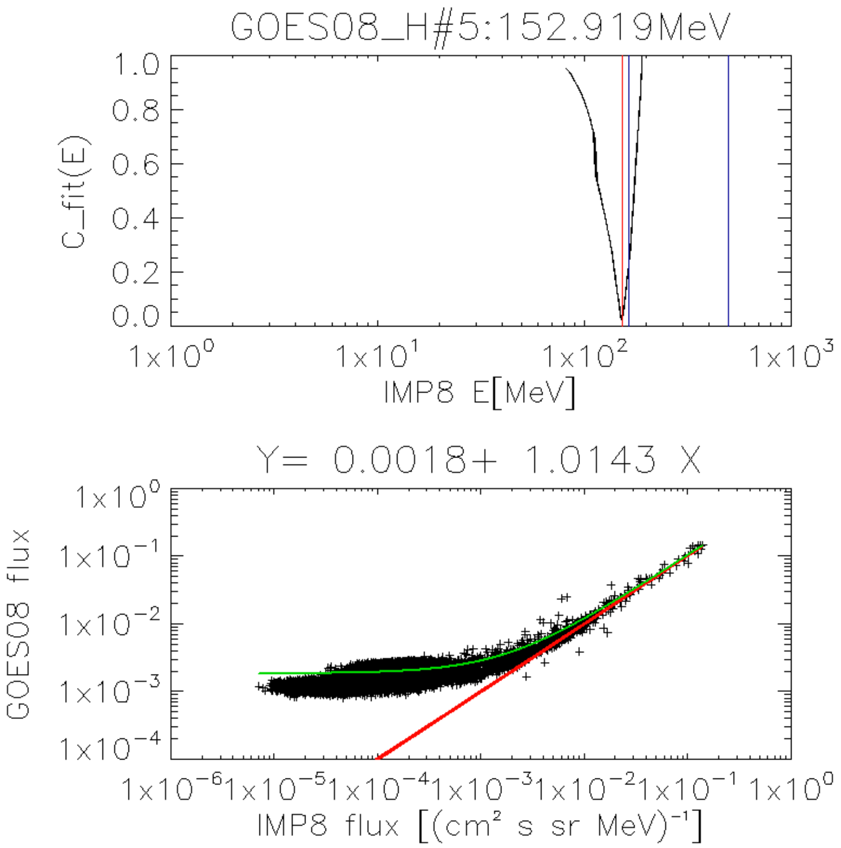

FIGURE 32 SEPCALIB ANALSIS FOR GOES08 CHANNEL P7

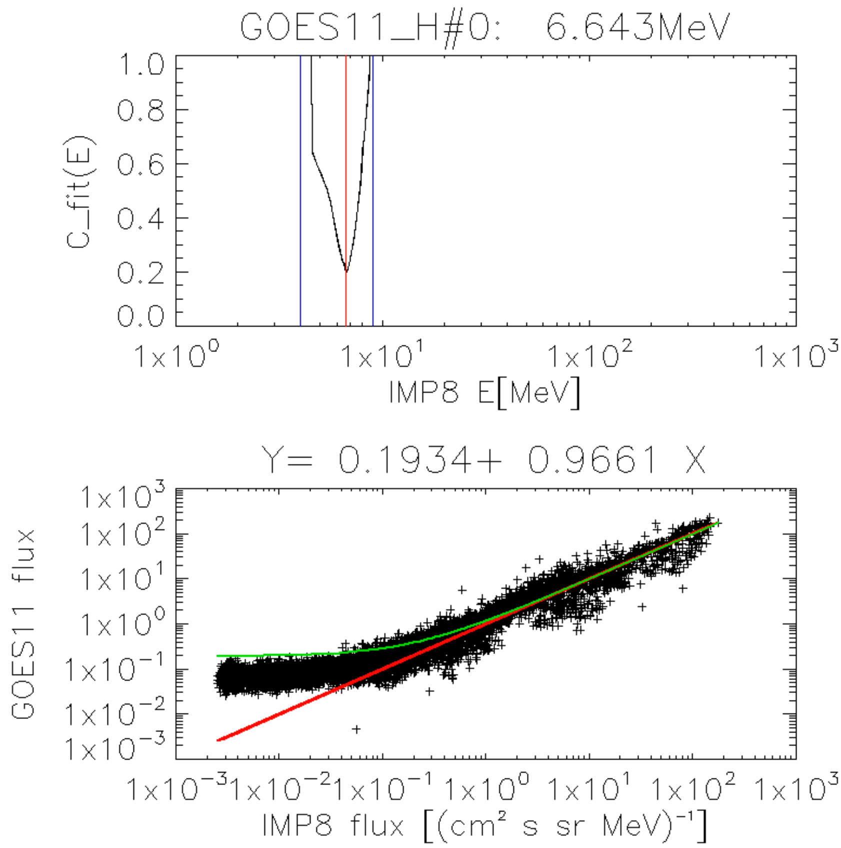

FIGURE 33 SEPCALIB ANALSIS FOR GOES11 CHANNEL P2

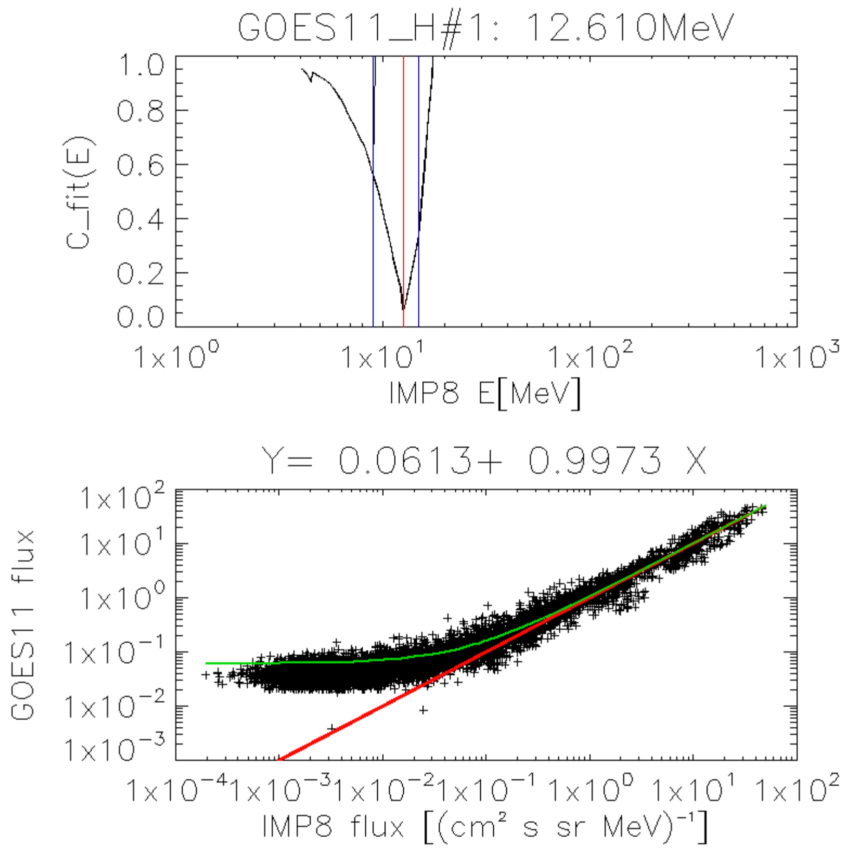

FIGURE 34 SEPCALIB ANALSIS FOR GOES11 CHANNEL P3

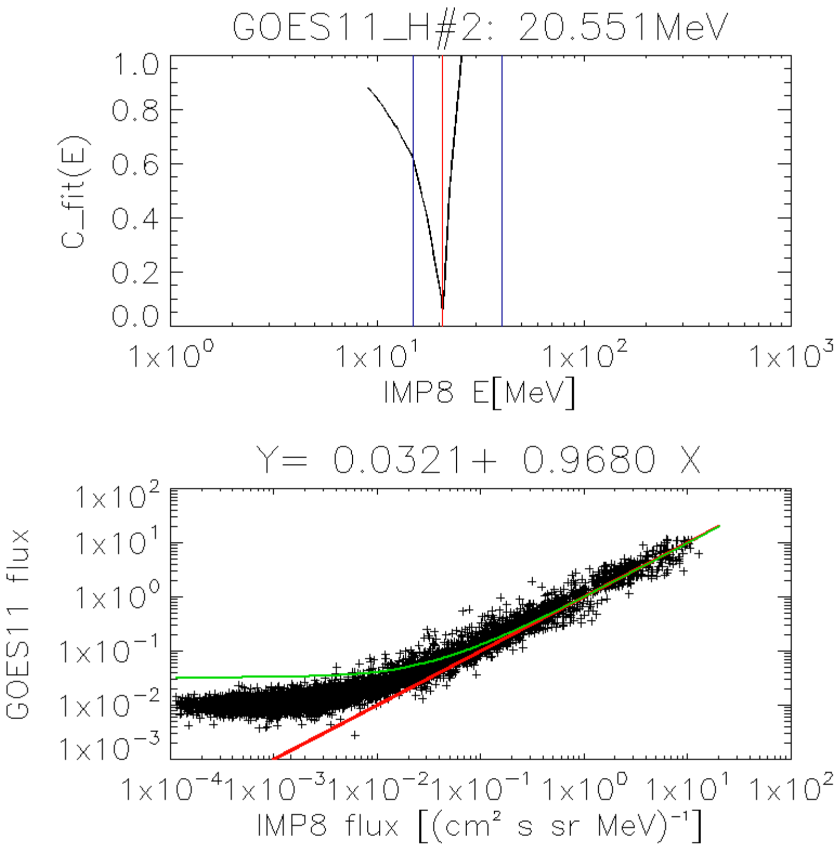

FIGURE 35 SEPCALIB ANALSIS FOR GOES11 CHANNEL P4

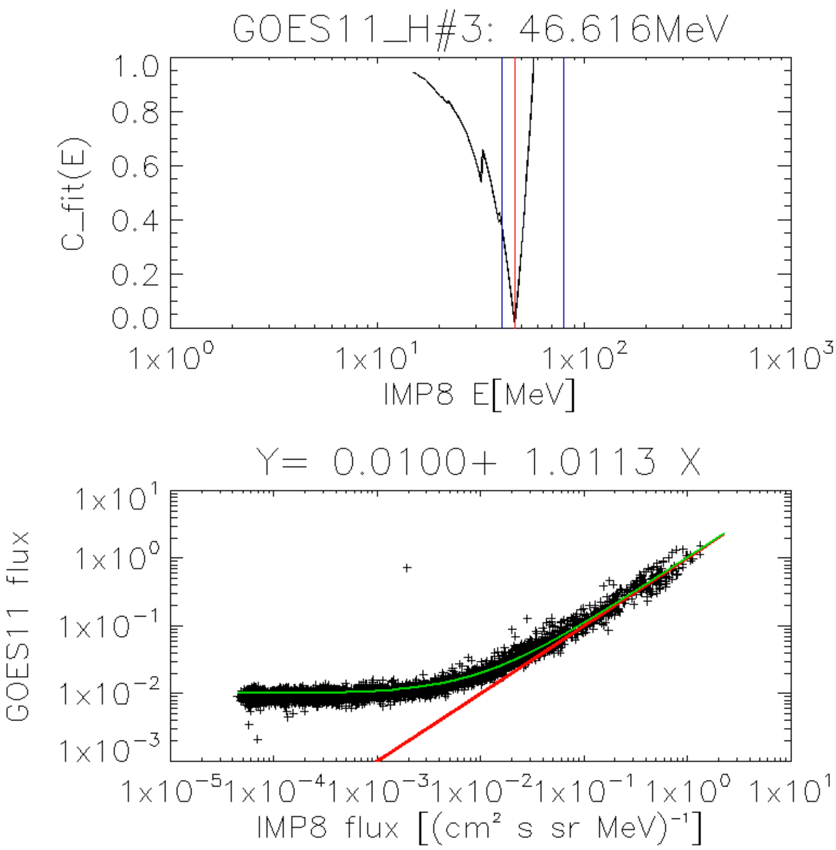

FIGURE 36 SEPCALIB ANALSIS FOR GOES11 CHANNEL P5

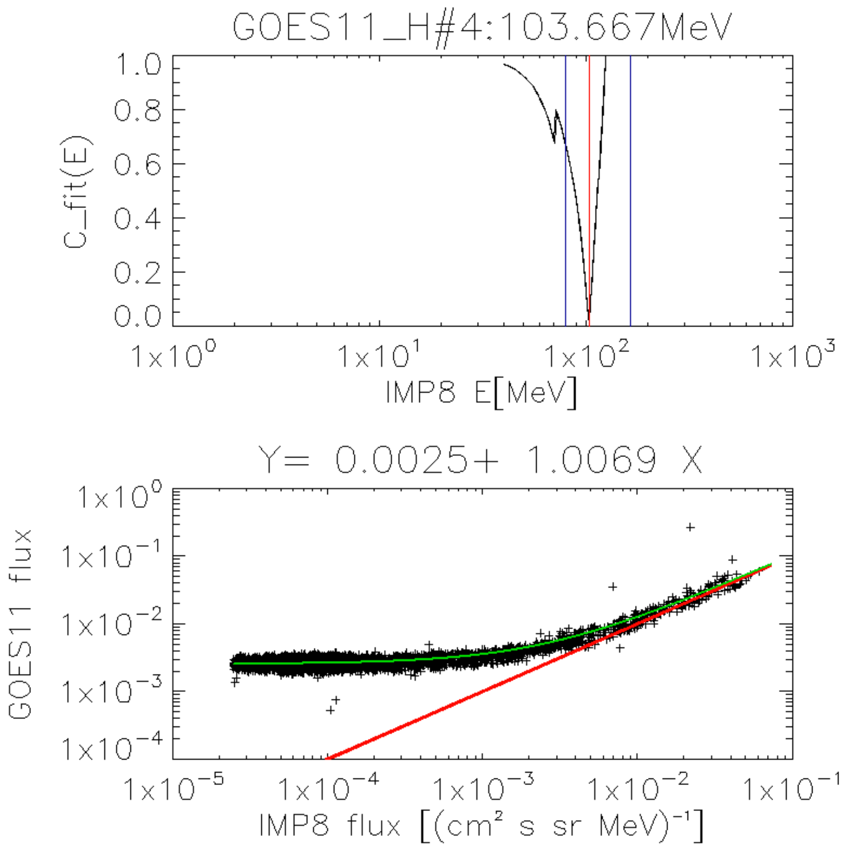

FIGURE 37 SEPCALIB ANALSIS FOR GOES11 CHANNEL P6

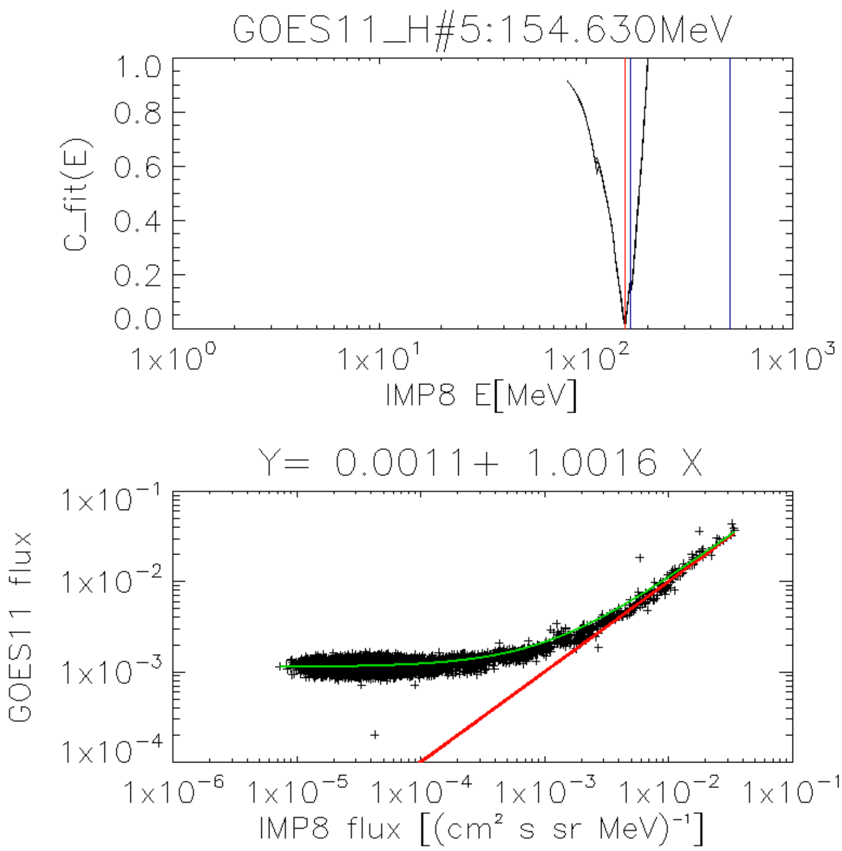

FIGURE 38 SEPCALIB ANALSIS FOR GOES11 CHANNEL P7

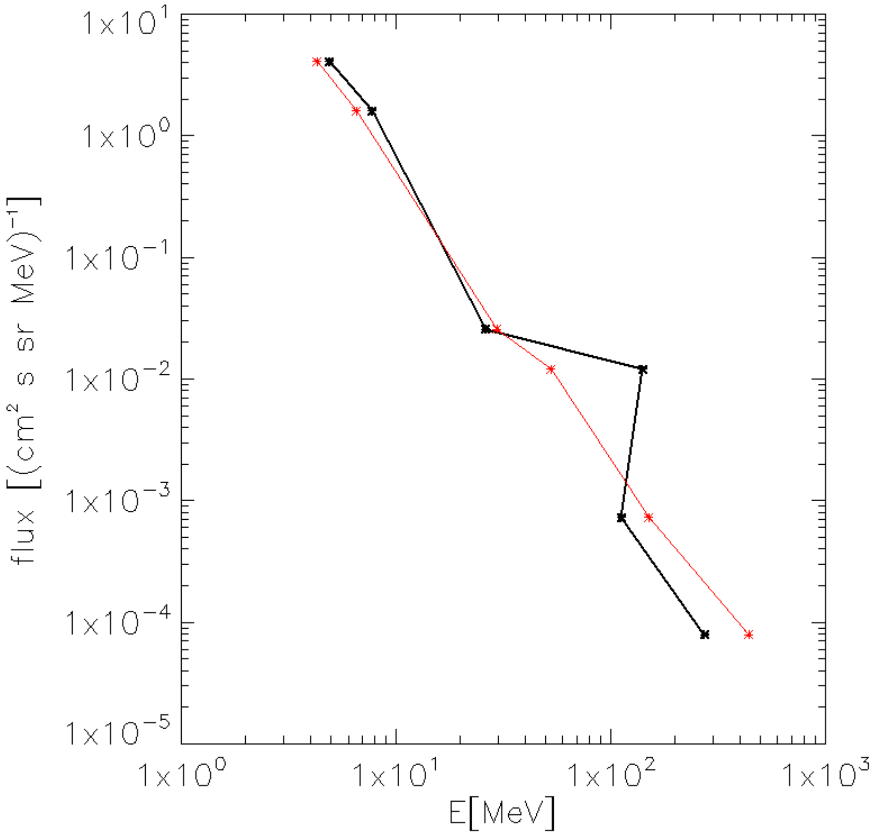

FIGURE 39 TOTAL H FLUENCE SPECTRA FOR THE COMBINED SMS1,2 DATASET

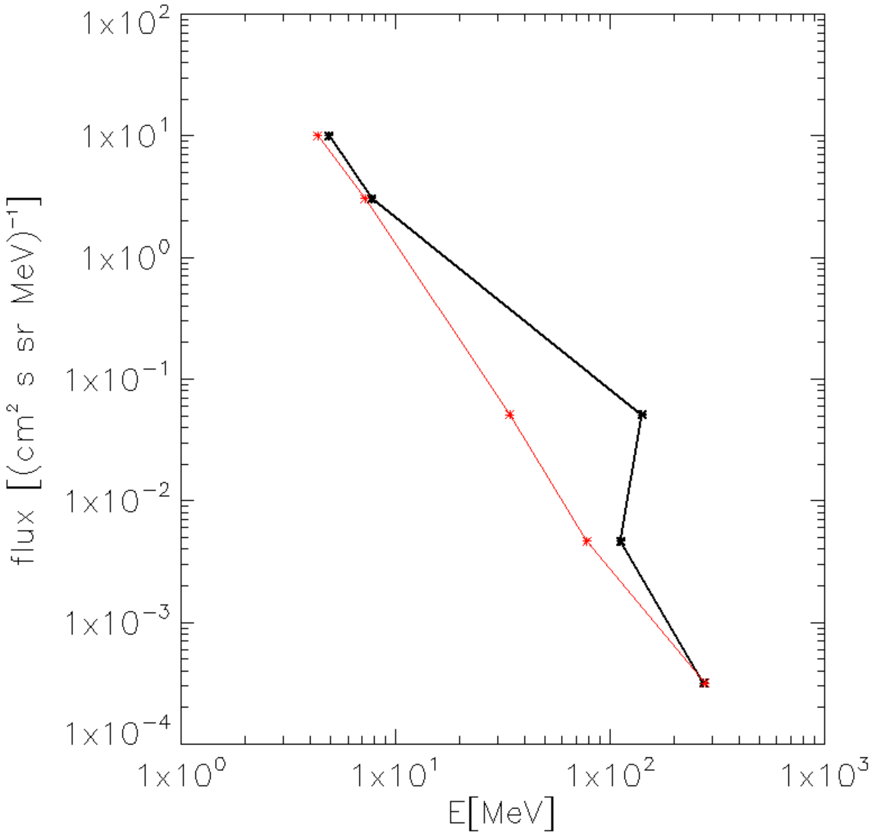

FIGURE 40 TOTAL H FLUENCE SPECTRA FOR THE COMBINED GOES01,02 DATASET

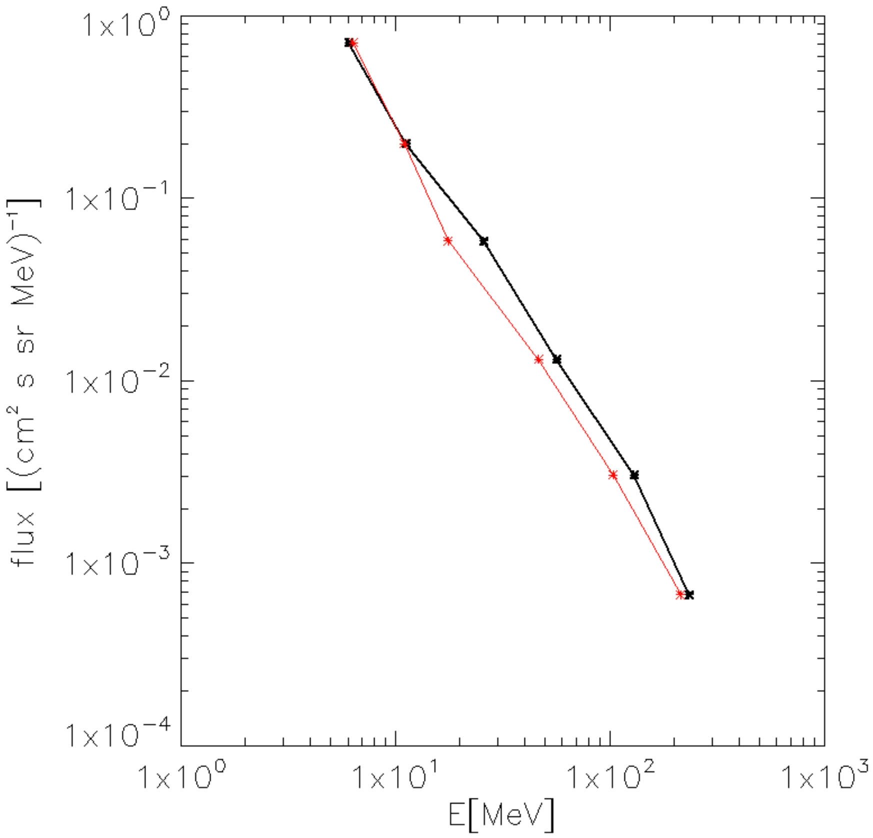

FIGURE 41 TOTAL H FLUENCE SPECTRA FOR THE GOES05 DATASET

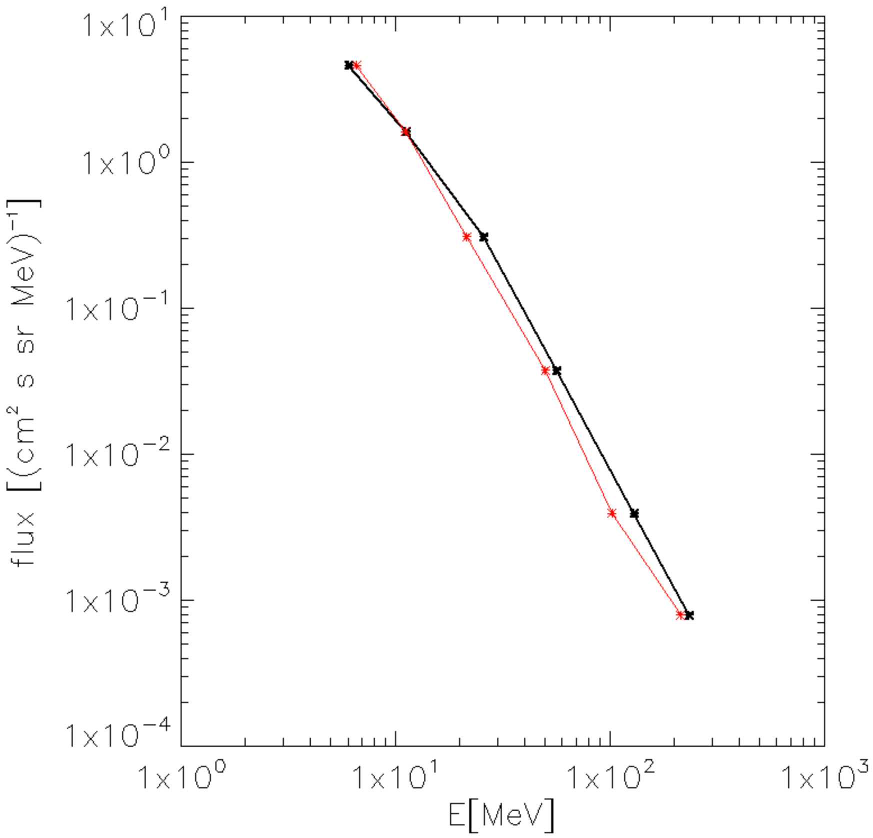

FIGURE 42 TOTAL H FLUENCE SPECTRA FOR THE GOES07 DATASET

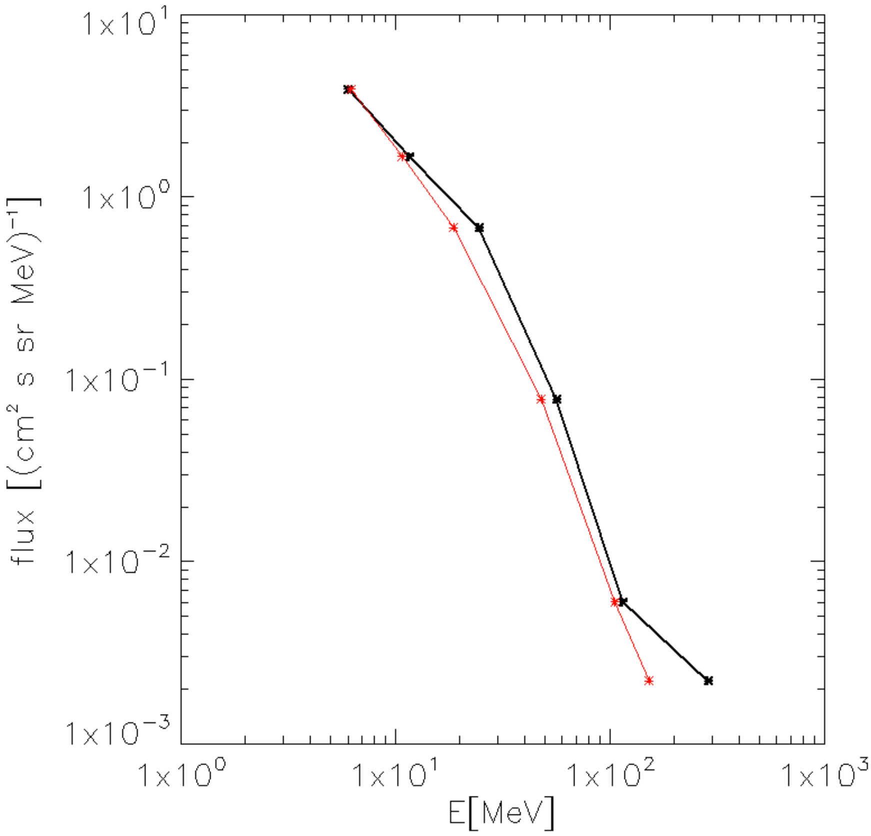

FIGURE 43 TOTAL H FLUENCE SPECTRA FOR THE GOES08 DATASET

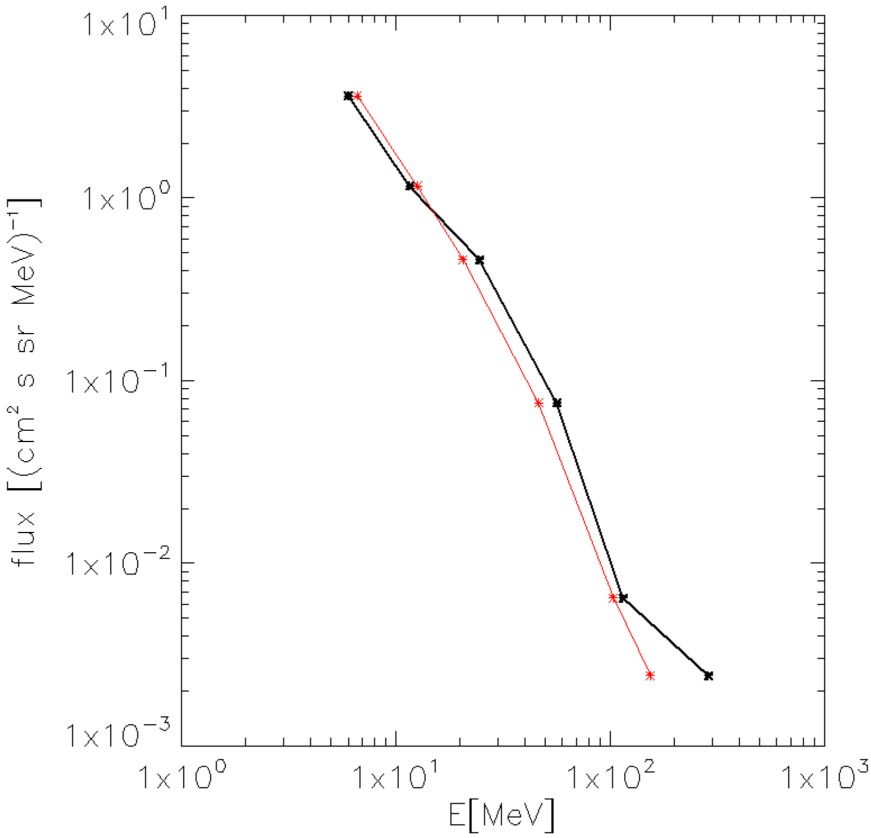

FIGURE 44 TOTAL H FLUENCE SPECTRA FOR THE GOES11 DATASET

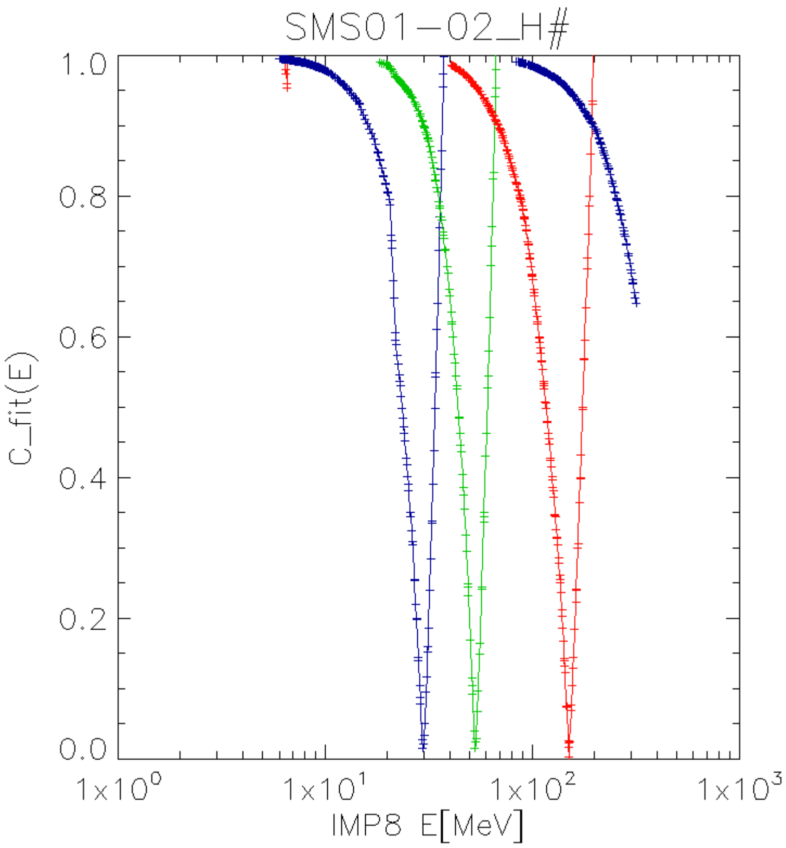

FIGURE 45 SEPCALIB GOODNESS OF FIT PARAMETER FOR THE COMBINED SMS1,2 DATASET

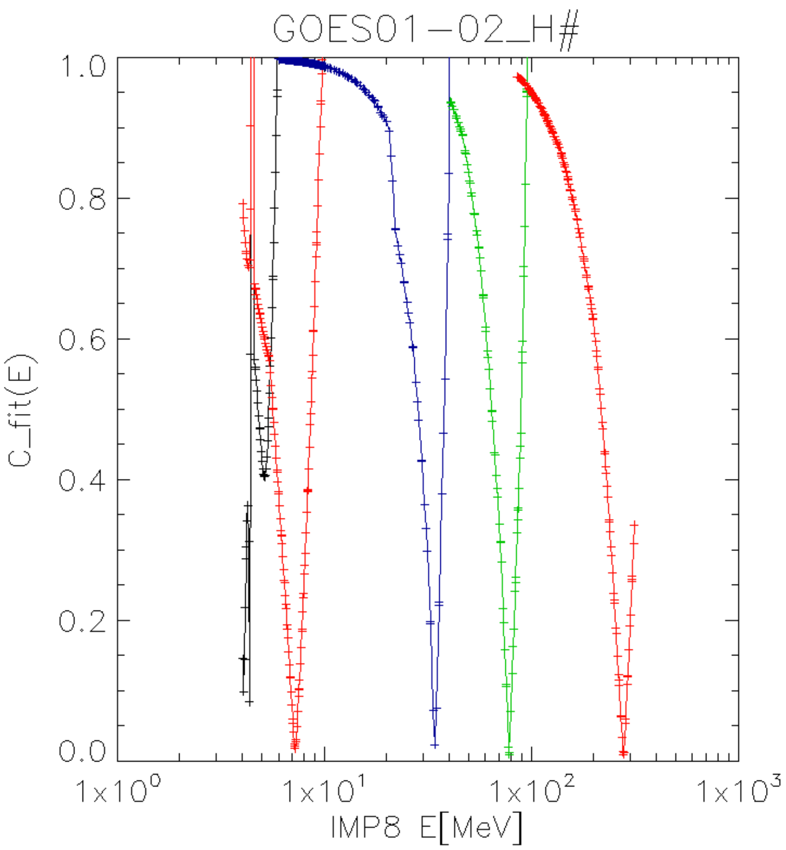

FIGURE 46 SEPCALIB GOODNESS OF FIT PARAMETER FOR THE COMBINED GOES01,02 DATASET

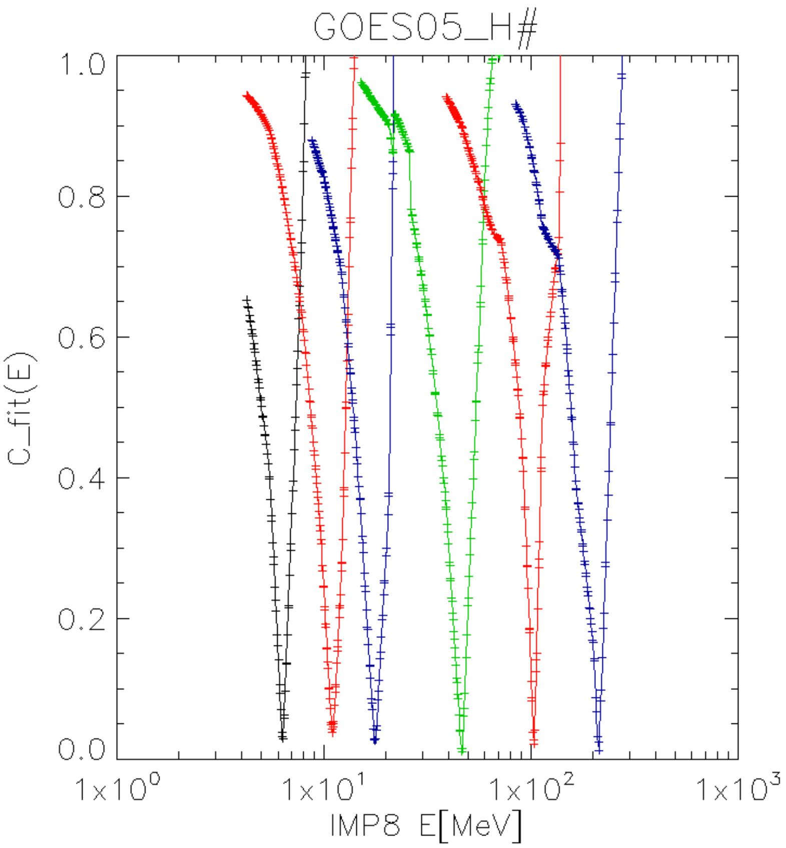

FIGURE 47 SEPCALIB GOODNESS OF FIT PARAMETER FOR THE GOES05 DATASET

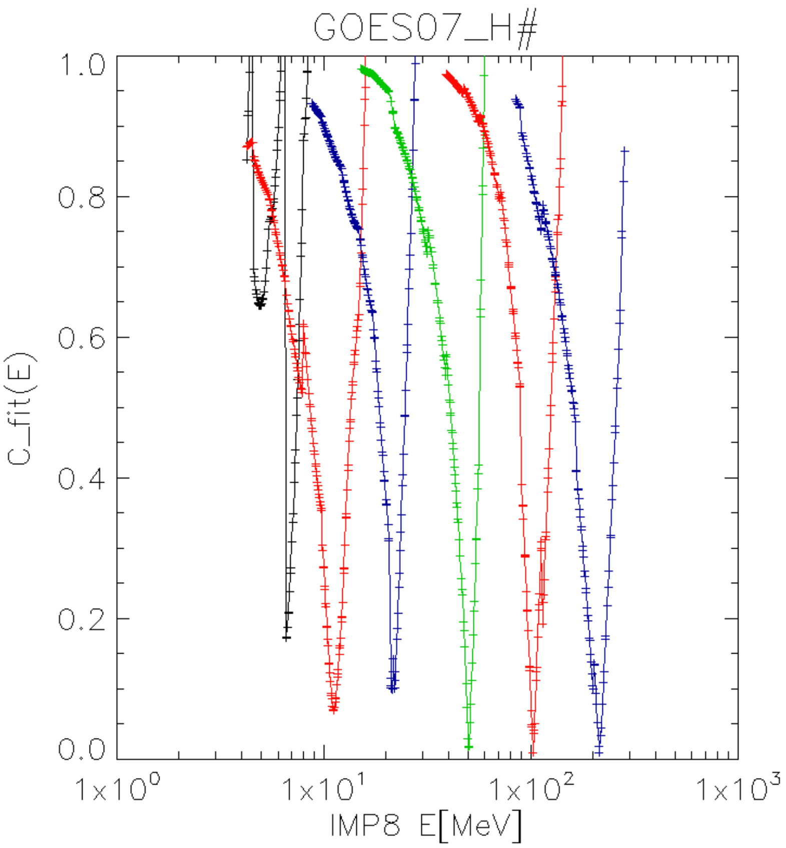

FIGURE 48 SEPCALIB GOODNESS OF FIT PARAMETER FOR THE GOES07 DATASET

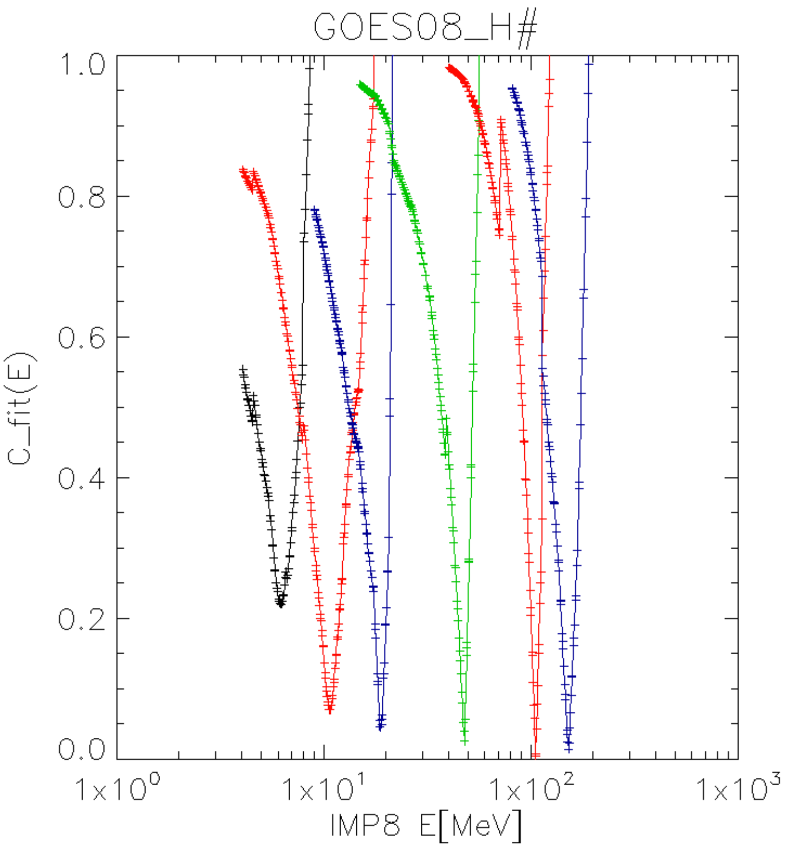

FIGURE 49 SEPCALIB GOODNESS OF FIT PARAMETER FOR THE GOES08 DATASET

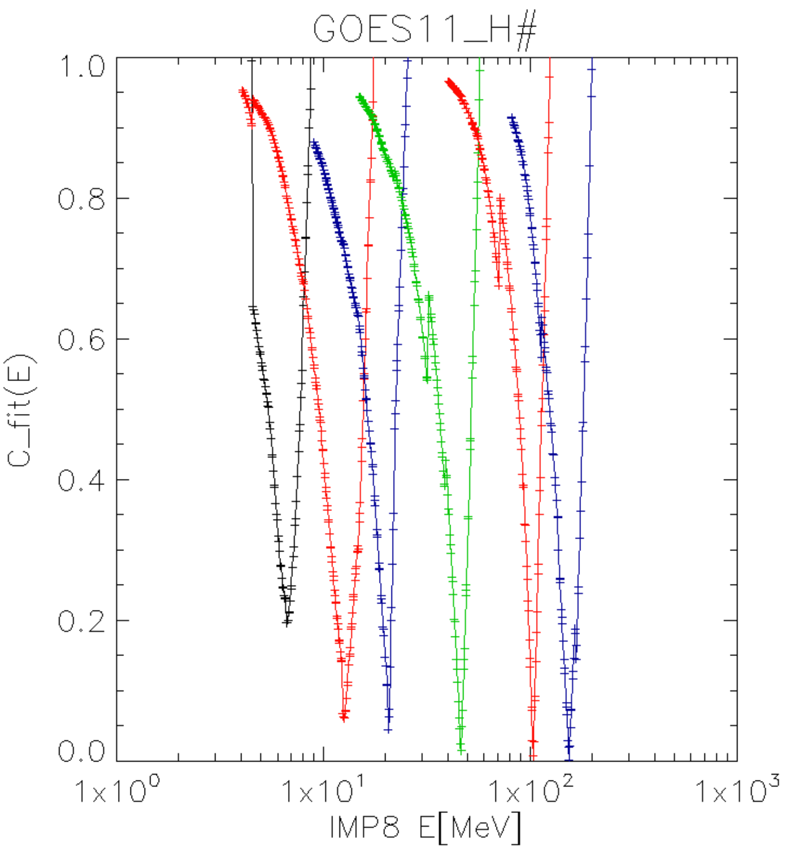

FIGURE 50 SEPCALIB GOODNESS OF FIT PARAMETER FOR THE GOES11 DATASET

The new central energies for the channels of the cleaned datasets, re-binned to 30 minute intervals, are listed in Table 3.

TABLE 3 GOES H CHANNEL CENTROID ENERGIES (MEV) OBTAINED WITH THE SEPCALIB ANALYSES USING DATA RE-BINNED IN 30 MINUTE INTERVALS

Channel	SMS1,2	GOES01,02	GOES05	GOES07	GOES08	GOES11-13
P2	4.282	4.347	6.348	6.591	6.214	6.643
P3	6.561	7.233	11.01	11.15	10.74	12.61
P4	29.59	–	17.56	21.54	18.65	20.55
P5	52.96	34.20	46.54	49.98	47.82	46.62
P6	150.7	78.29	103.8	102.4	105.6	103.7
P7	440.8	278.5	213.6	214.4	152.9	154.6

6 DATASET MERGING

The cleaned and re-binned GOES datasets were merged into a single SEPEM data table (`sepem_rds_2_0_h`) in order to create a single contiguous reference dataset. The data time periods used for each spacecraft are listed in Table 4. When there is an overlap between successive GOES spacecraft, the best quality data is used. All data was used for the SEPCALIB process.

TABLE 4 DATA SELECTION FOR THE REFERENCE H DATASET

Dataset	Original Time Span	Time Span of Selected Data	Comments
SMS01/EPS	01/07/1974–31/10/1975	01/07/1974–31/01/1975	
SMS02/EPS	01/02/1975-31/03/1978	01/02/1975-31/03/1977	
GOES01/EPS	01/01/1976-31/05/1978	01/04/1977-31/07/1977	Channel P4 is corrupted.
GOES02/EPS	01/08/1977-31/05/1983	01/08/1977-19/05/1983	Channel P4 is corrupted.
GOES03/EPS	01/01/1978-31/12/1979		Not used.
GOES05/EPS	01/01/1984-25/03/1987	01/01/1984-05/03/1987	Missing data for Dec 1985 were set to background levels.
GOES06/EPS	01/05/1983-31/12/1994	20/05/1983-31/12/1983	GOES06 data were used for this period (no SPE occurrence) to bridge the gap with GOES05.
GOES07/EPS	06/03/1987-31/08/1996	06/03/1987-31/12/1994	
GOES08/EPS	01/01/1995-17/06/2003	01/01/1995-16/06/2003	
GOES09/EPS	01/01/1997-31/08/1998		Not used.
GOES10/EPS	01/07/1998-31/12/2009		Not used.
GOES11/EPS	01/07/2000-28/02/2011	17/06/2003-31/01/2011	Due to large data gaps, data prior to 21/06/2003 are only used for cross-calibration. Data from GOES12 were used for 1–19/06/2003.
GOES12/EPS	01/01/2003-30/09/2010	01/06/2003-19/06/2003	Only used for patching two weeks of GOES11 data.
GOES13/EPEAD	01/05/2010-3/12/2017	01/02/2011-31/12/2017	Data for 22–03/05/2013 were patched with GOES15 data.

7 Background subtraction

Due to the relatively high instrument background in the GOES H channels, a background subtraction was performed to the cross calibrated and merged SEPEM H dataset. The background subtraction algorithm consists of the following steps (per energy channel):

1. Use an event list to identify quiet and active periods.
2. For each day in the dataset, calculate the average flux over the three days centred on the day, if all three days fall in a contiguous quiet period. If not, find the closest three day contiguous quiet periods before and after the event (this can result in merging event periods which are separated by less than 3 days). This procedure sets the background level for each day in the dataset.
3. For each day in the dataset, find the minimum non-zero flux value.
4. For each day in the dataset, subtract the daily background flux from all fluxes.
5. If the background subtracted flux value is below the original minimum flux for the day, set it to zero.

At first, the SEPEM reference event list was used for step 1. However, this list was built using a mixture of IMP-8/GME and GOES/EPS data (the original reference H dataset). In addition, due to the data noise, the event start and stop times are not always correctly defined (typically, event durations tend to be too short as the data noise makes the flux dip below the end threshold flux prematurely). Therefore, a new event list was built using the new H reference dataset, after re-binning in 1 hour time intervals to remove the data noise. For each successive spacecraft era, the start and end event threshold values were set to best reflect the data background levels.

The effect of using 1 hour averaged data on the event lists is illustrated in Figure 51 and Figure 52, for the March 1991 event. The first figure shows 5 channels (including the 7.23–10.46 MeV channel which is currently used to define the reference event list) of the reference H dataset for the time period 23 March – 13 April 1991. In the reference event list, this time period is split into two separate events: 23–31 March, and 2–10 April. The second figure shows the same data period, but now after averaging the data over 1 hour time intervals. The flux threshold level for the event list is 0.1. This is attained in both figures around midnight of 1 April. On 2 April, the 5 minute fluxes repeatedly dip below 0.1 again, which causes a separation of more than 1 day with the second period of enhancement starting on 3 April, which is interpreted as the start of a new event. In the 1 hour averaged data, the flux only dips below 0.1 on 1 April, so there is no separation. In addition, the second event in the reference list ends at 01 hours on 10 April (due to the scatter in the data), while the average flux is still going down for at least two days.

Figure 53 – Figure 63 show the final reference H dataset flux after background subtraction for the individual reference energy channels as daily averages.

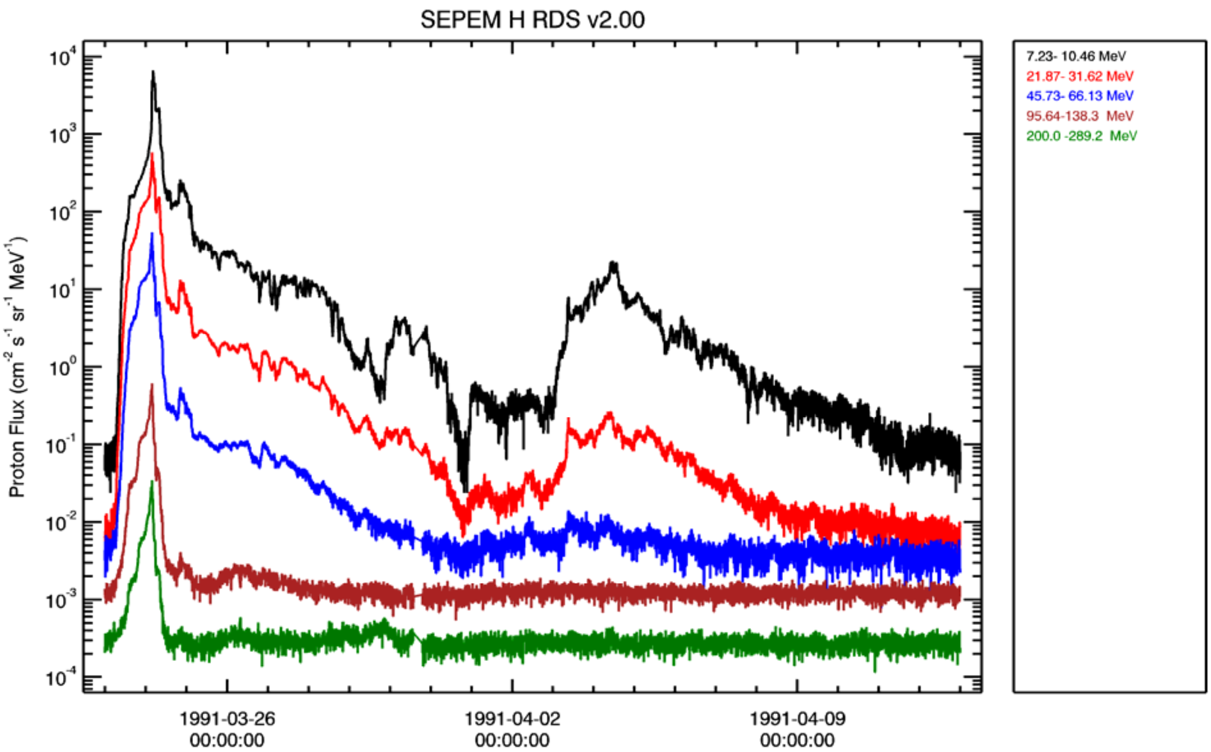

FIGURE 51 H REFERENCE DATASET CHANNELS FOR THE TIME PERIOD 23 MARCH – 13 APRIL 1991

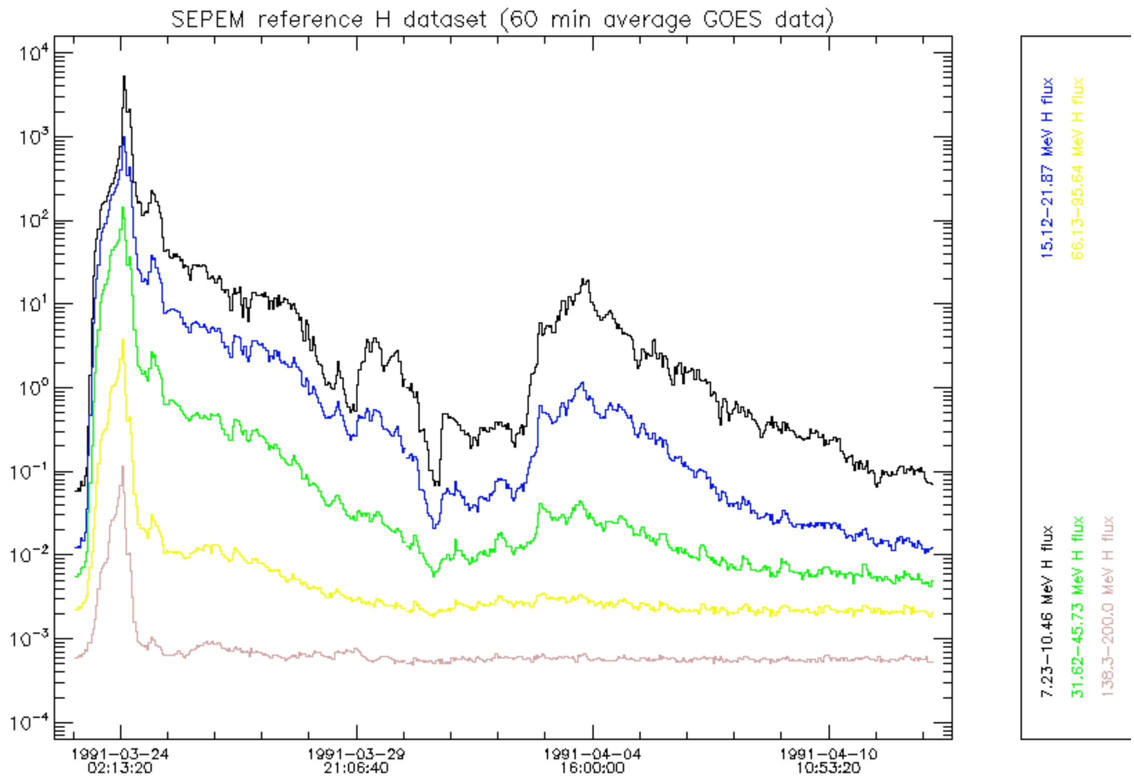

FIGURE 52 H REFERENCE DATASET CHANNELS FOR THE TIME PERIOD 23 MARCH – 13 APRIL 1991 AFTER RE-BINNING INTO 1 HOUR TIME INTERVALS

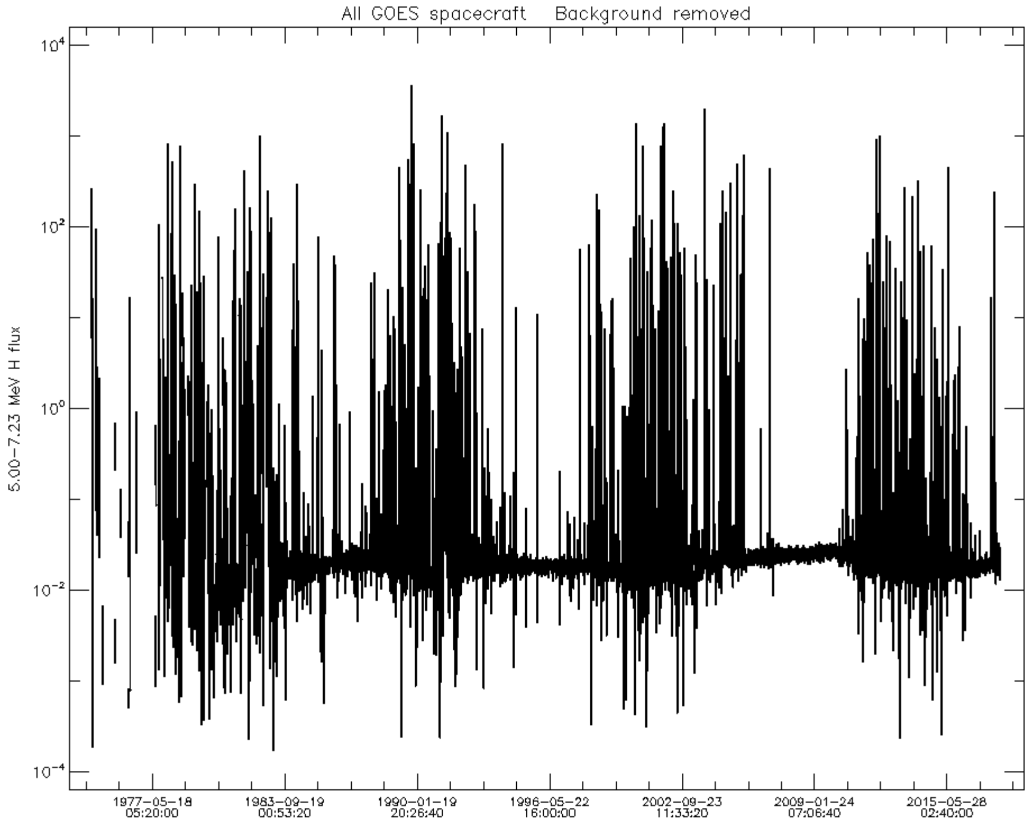

FIGURE 53 DAILY AVERAGE FLUX FOR CHANNEL 1 OF THE H REFERENCE DATASET AFTER BACKGROUND SUBTRACTION

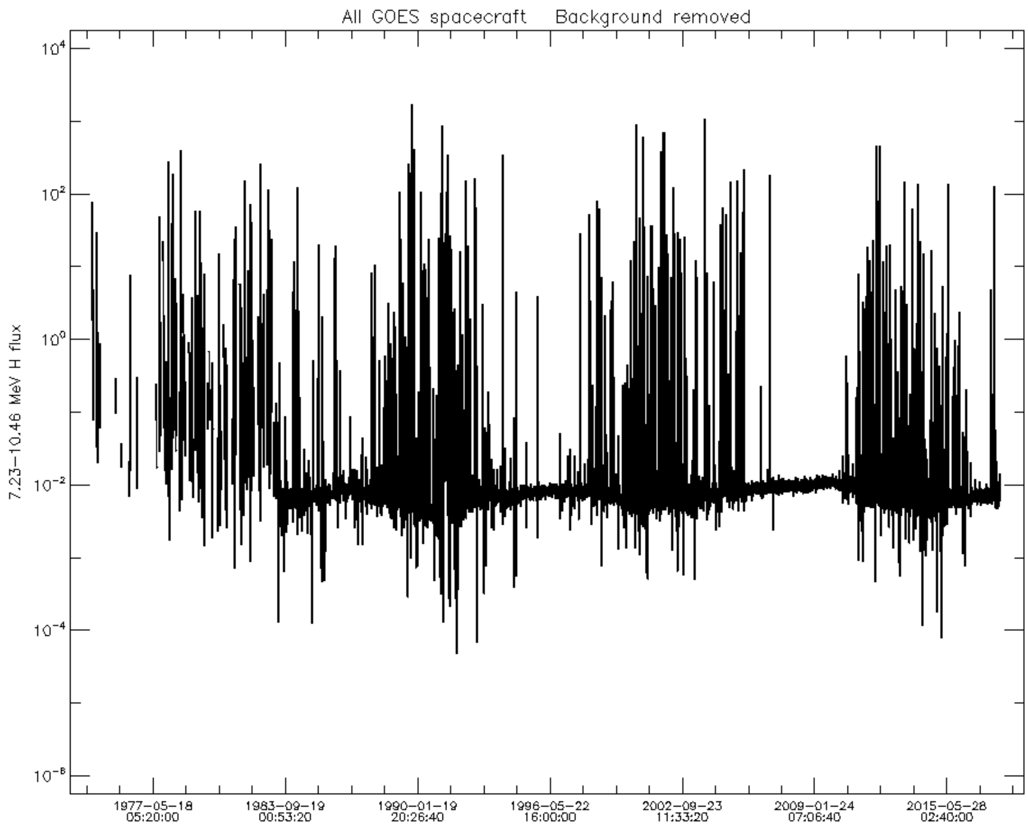

FIGURE 54 DAILY AVERAGE FLUX FOR CHANNEL 2 OF THE H REFERENCE DATASET AFTER BACKGROUND SUBTRACTION

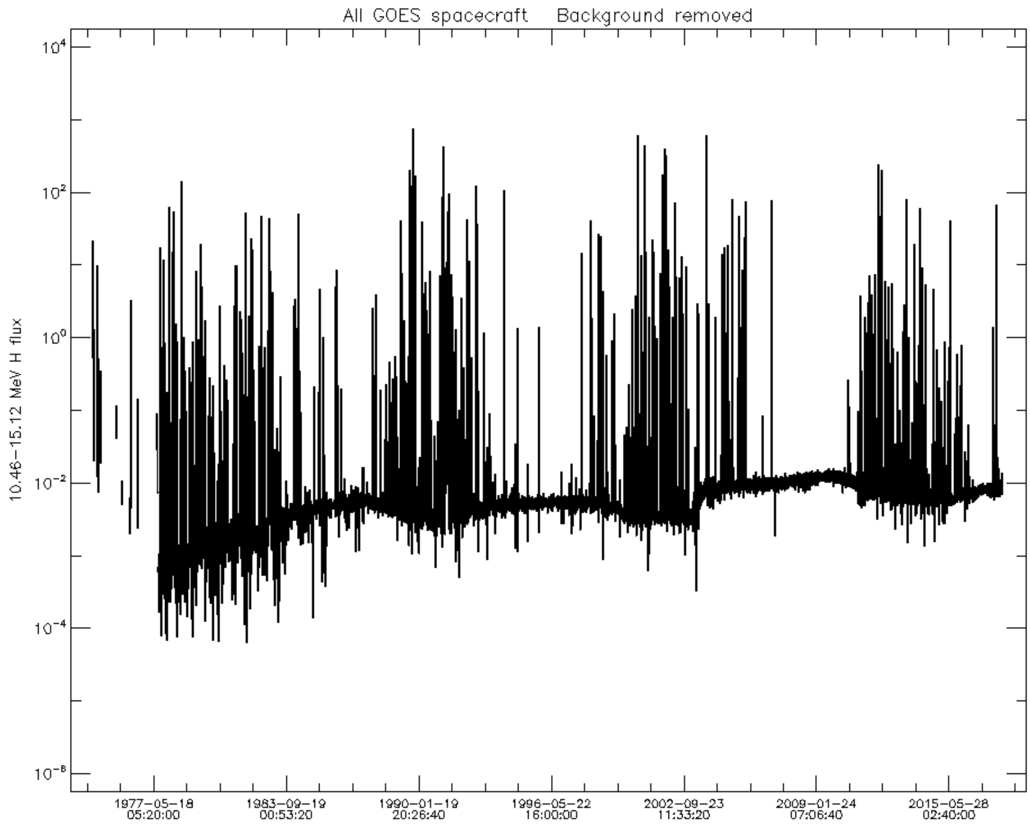

FIGURE 55 DAILY AVERAGE FLUX FOR CHANNEL 3 OF THE H REFERENCE DATASET AFTER BACKGROUND SUBTRACTION

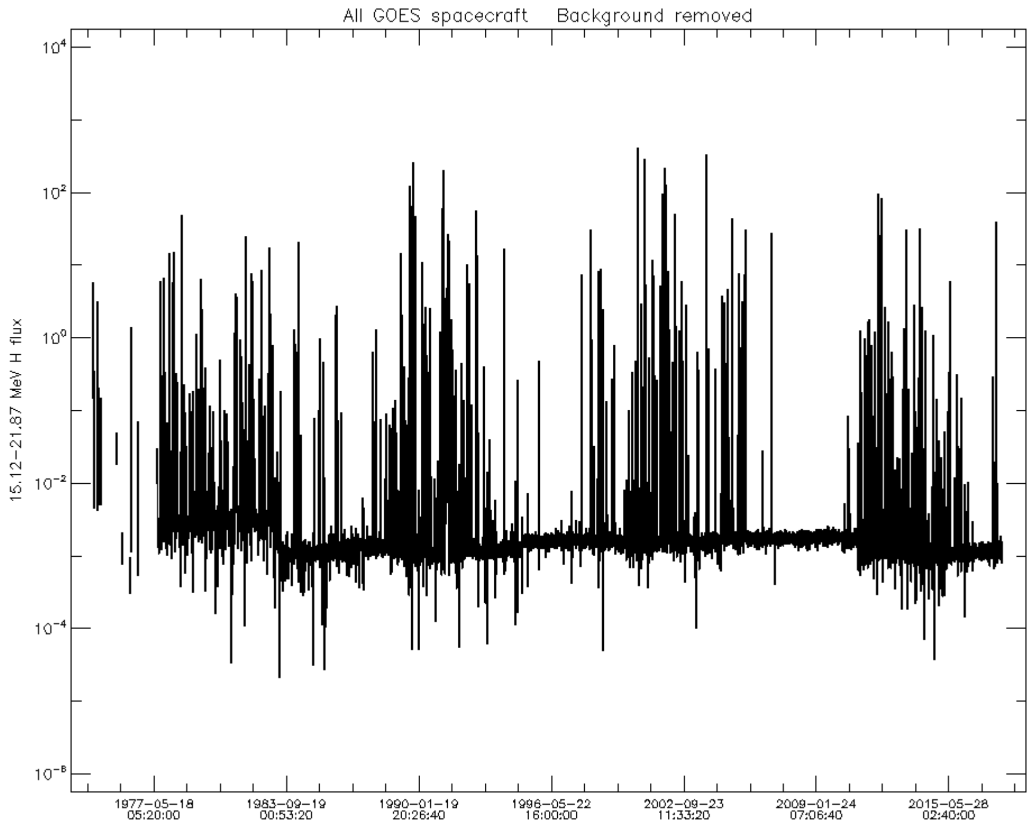

FIGURE 56 DAILY AVERAGE FLUX FOR CHANNEL 4 OF THE H REFERENCE DATASET AFTER BACKGROUND SUBTRACTION

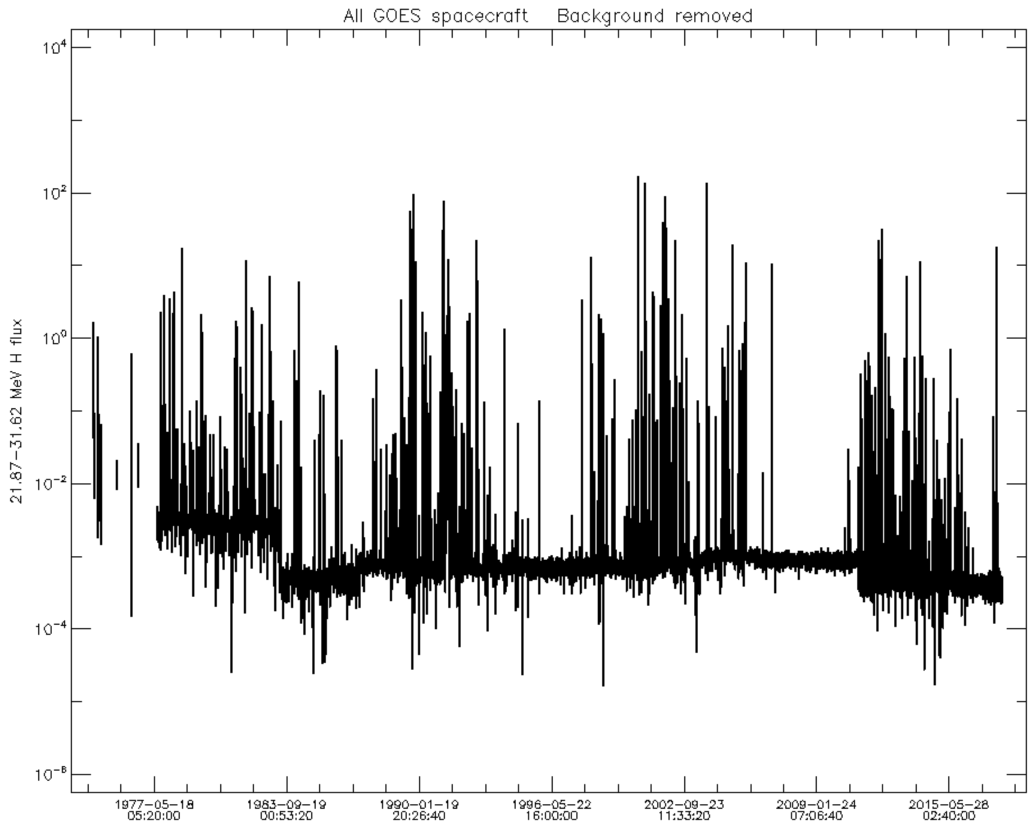

FIGURE 57 DAILY AVERAGE FLUX FOR CHANNEL 5 OF THE H REFERENCE DATASET AFTER BACKGROUND SUBTRACTION

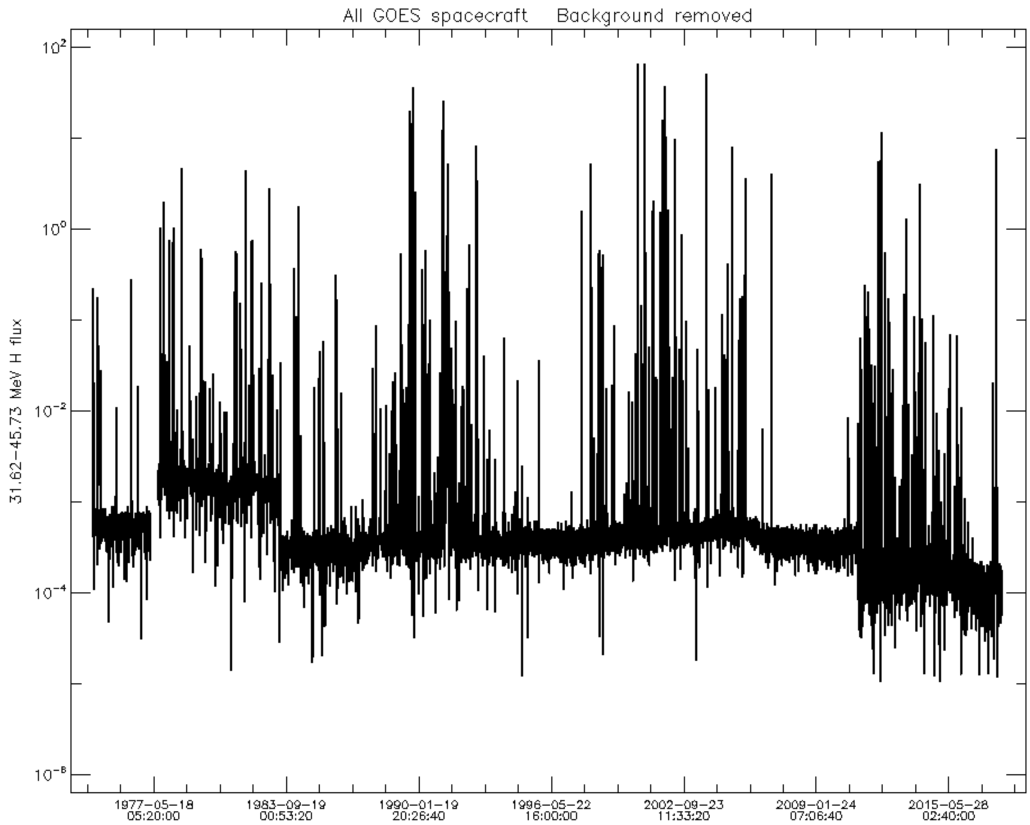

FIGURE 58 DAILY AVERAGE FLUX FOR CHANNEL 6 OF THE H REFERENCE DATASET AFTER BACKGROUND SUBTRACTION

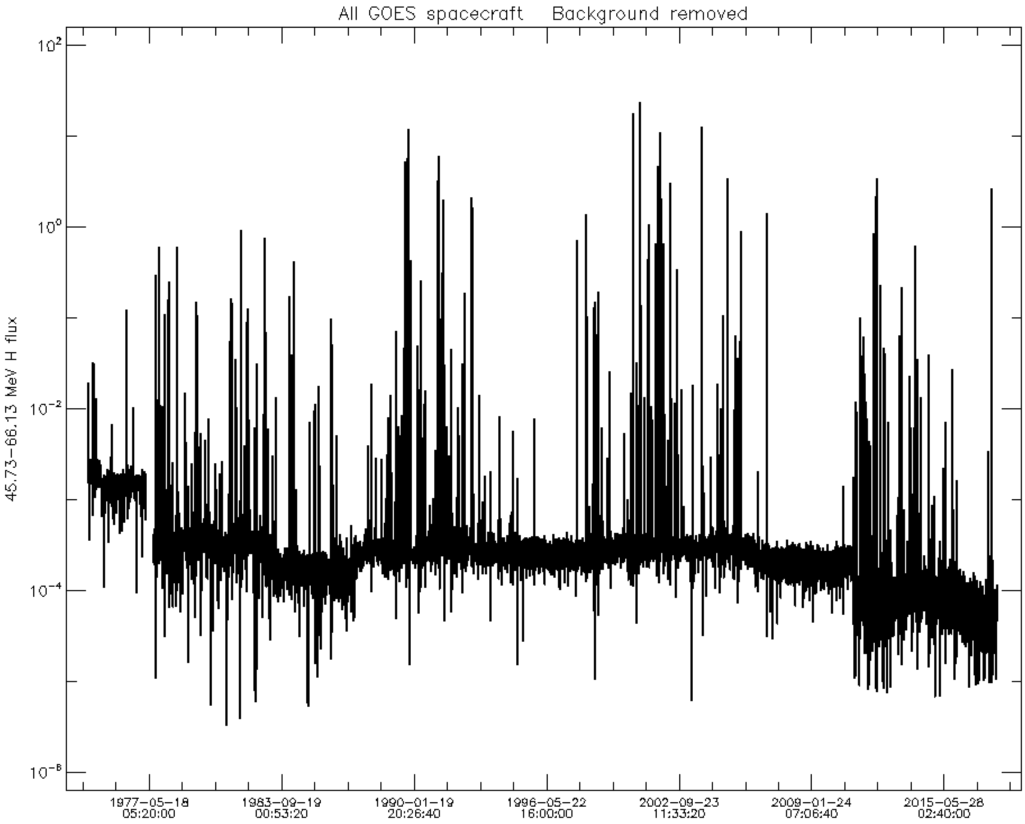

FIGURE 59 DAILY AVERAGE FLUX FOR CHANNEL 7 OF THE H REFERENCE DATASET AFTER BACKGROUND SUBTRACTION

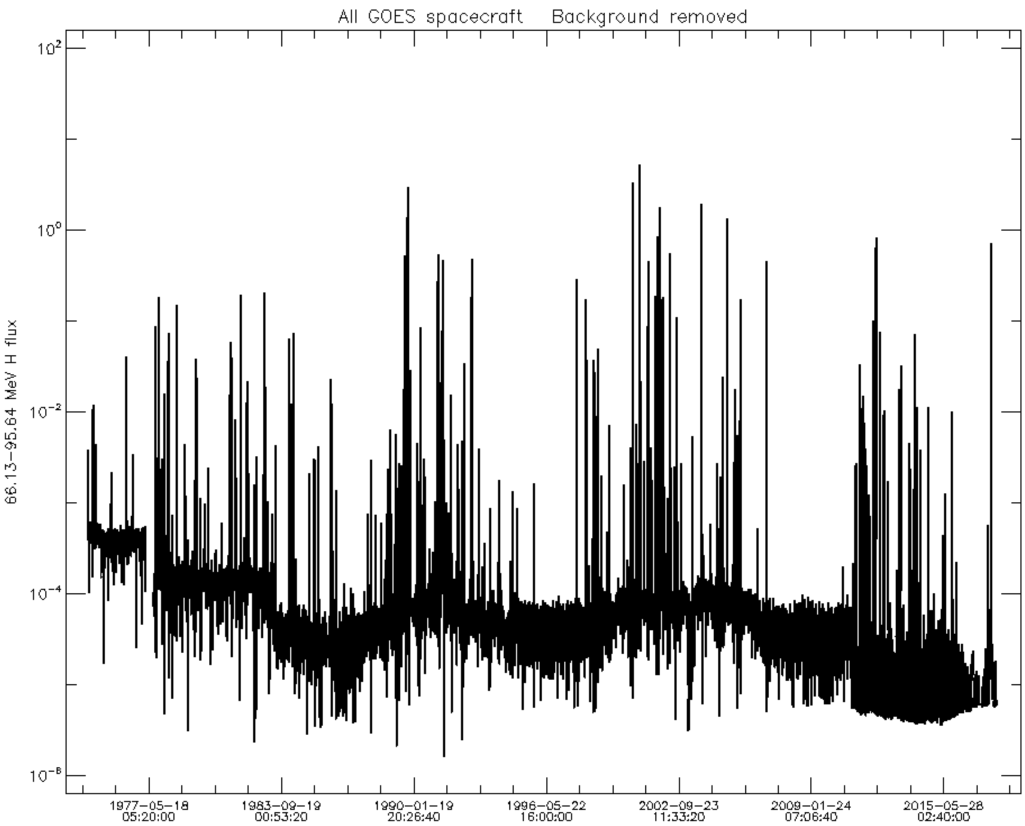

FIGURE 60 DAILY AVERAGE FLUX FOR CHANNEL 8 OF THE H REFERENCE DATASET AFTER BACKGROUND SUBTRACTION

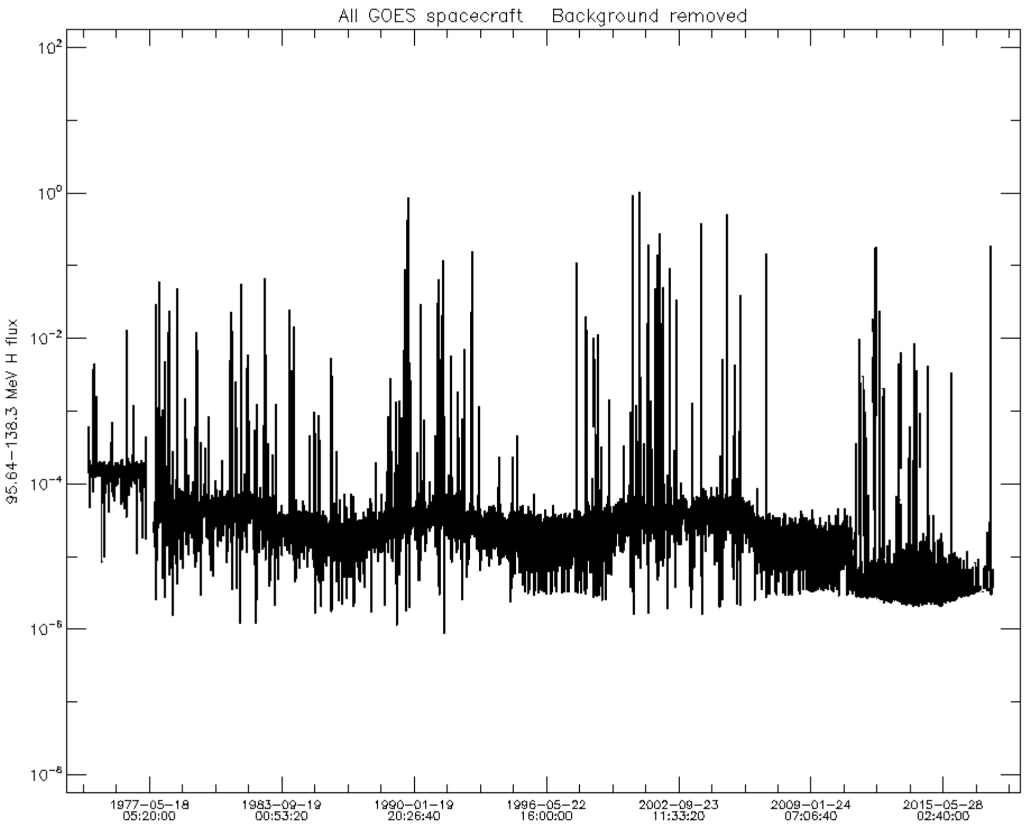

FIGURE 61 DAILY AVERAGE FLUX FOR CHANNEL 9 OF THE H REFERENCE DATASET AFTER BACKGROUND SUBTRACTION

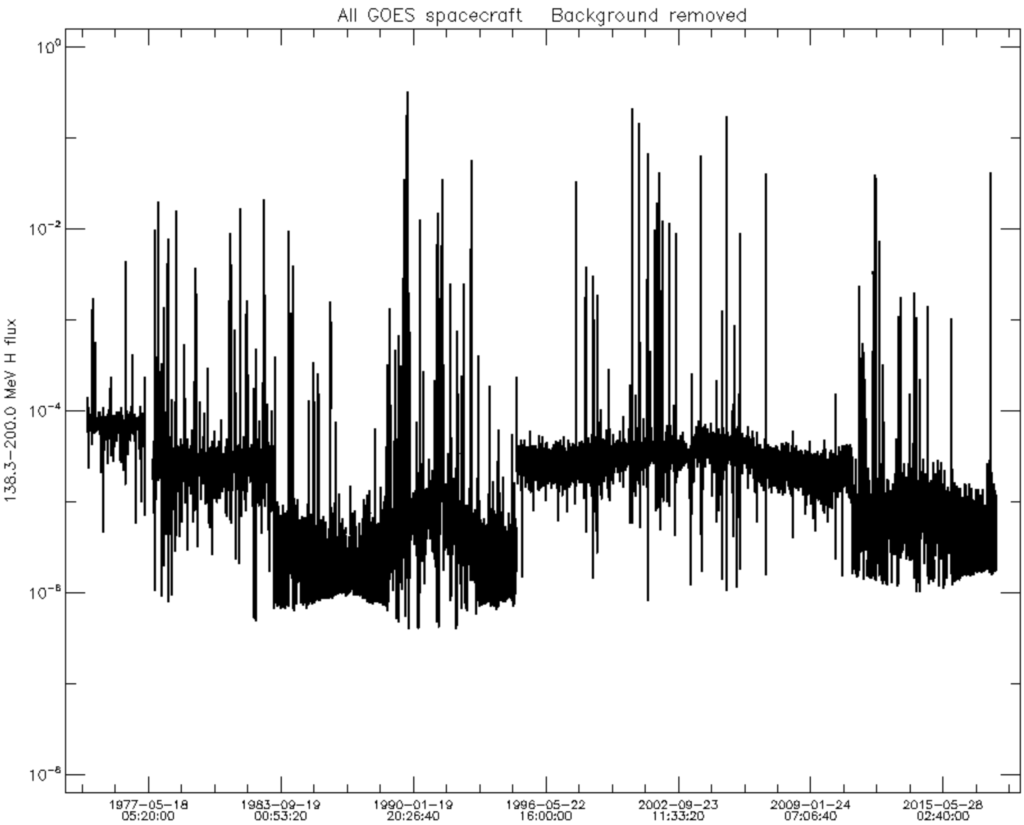

FIGURE 62 DAILY AVERAGE FLUX FOR CHANNEL 10 OF THE H REFERENCE DATASET AFTER BACKGROUND SUBTRACTION

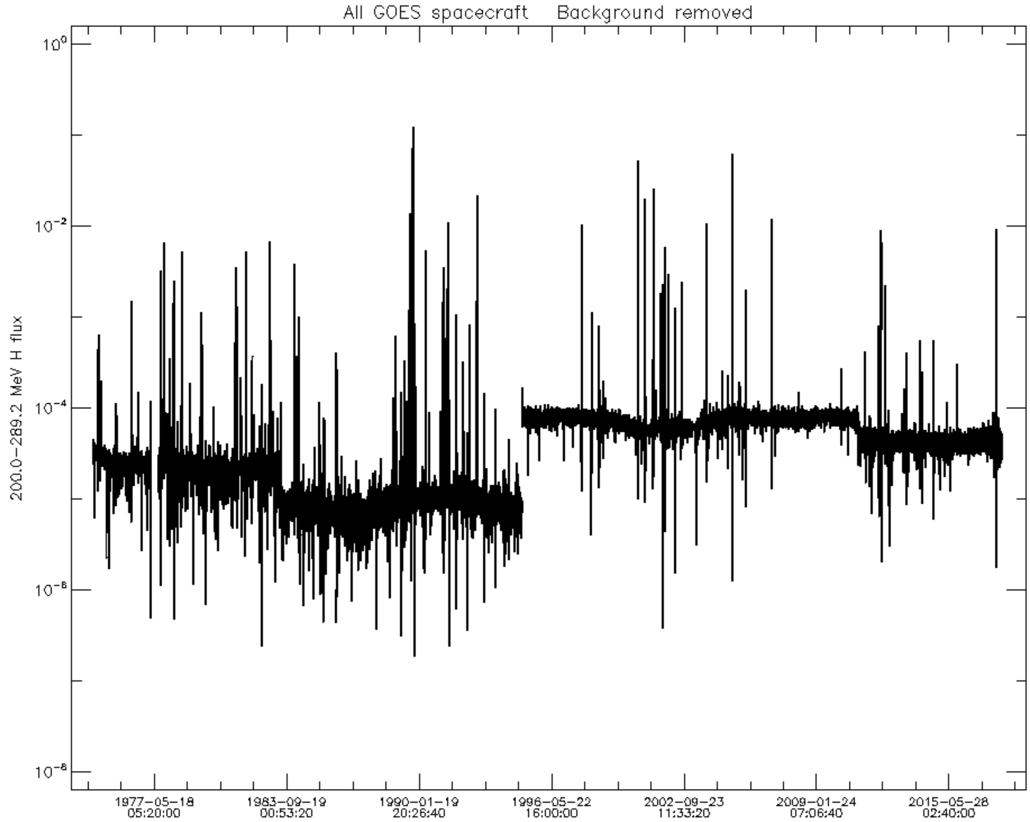

FIGURE 63 DAILY AVERAGE FLUX FOR CHANNEL 11 OF THE H REFERENCE DATASET AFTER BACKGROUND SUBTRACTION

In hindsight, it appears that steps 3–5 in the procedure outlined above tend to remove too many non-background fluxes in the descending phase of some events. This is illustrated in Figure 64, which shows the H reference data for the August 1998 event.

An improved procedure consists of replacing steps 3–5 by the following rule: if a flux value at least 20% above the background level, subtract the background flux level; in all other cases, set the flux to zero. Figure 65 shows the H data obtained with the updated background subtraction procedure for the August 1998 event. The original, very evident gaps in the data have now disappeared. It is recommended to use the updated procedure for the next release of the reference dataset.

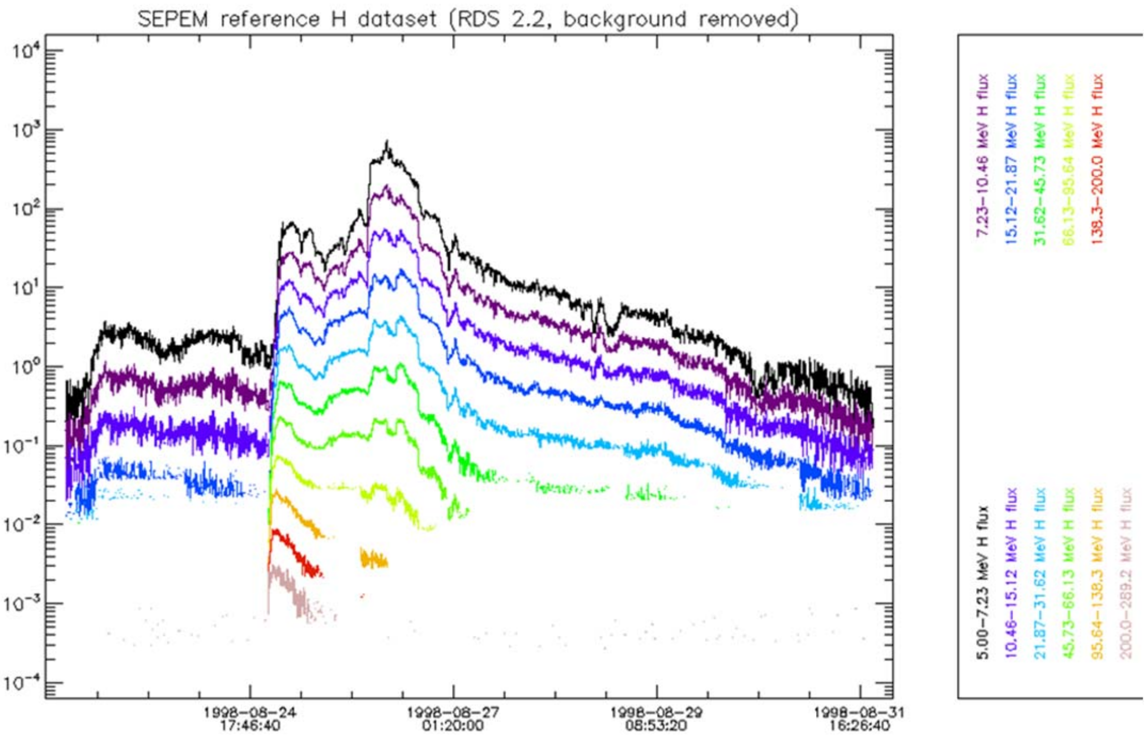

FIGURE 64 H REFERENCE DATASET FOR THE AUG 1998 EVENT, USING THE CURRENT BACKGROUND SUBTRACTION PROCEDURE

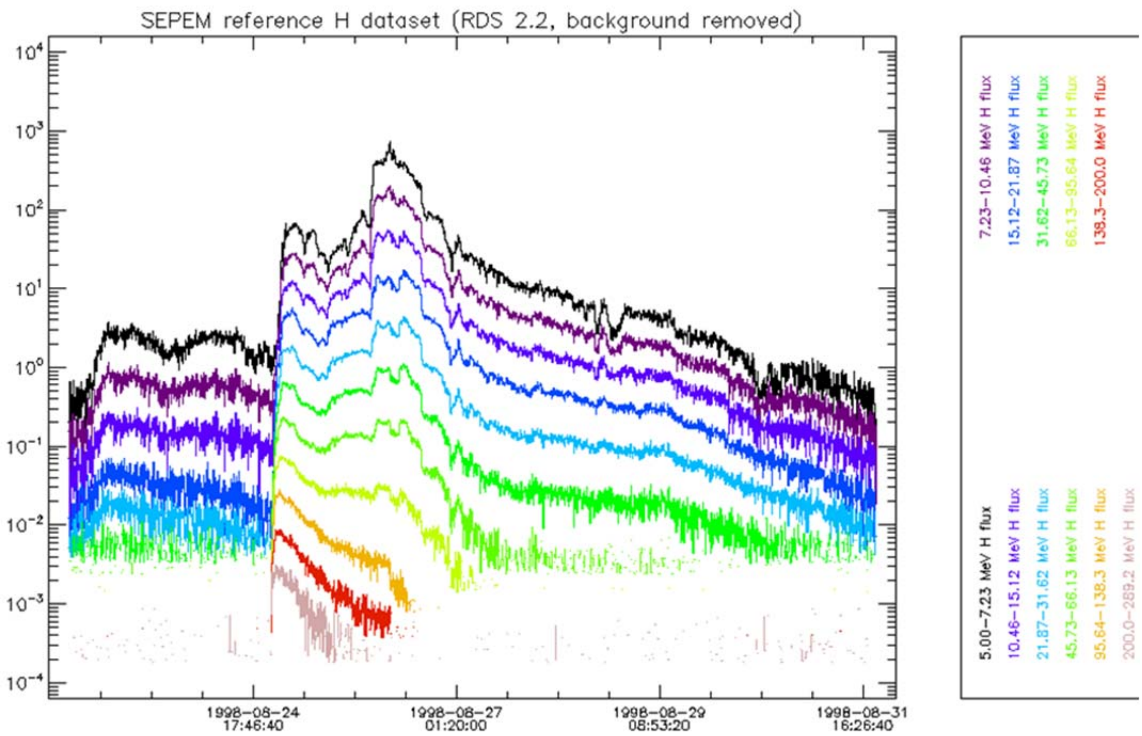

FIGURE 65 H REFERENCE DATASET FOR THE AUG 1998 EVENT, USING THE UPDATED BACKGROUND SUBTRACTION PROCEDURE